US009303614B2

(12) United States Patent
Shoda et al.

(10) Patent No.: US 9,303,614 B2

(45) Date of Patent: Apr. 5, 2016

(54) INTERNAL COMBUSTION ENGINE AUTOMATIC STOP/RESTART DEVICE AND INTERNAL COMBUSTION ENGINE AUTOMATIC STOP/RESTART METHOD

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 408 days.

(21) Appl. No.: **14/010,768**

(22) Filed: **Aug. 27, 2013**

(65) **Prior Publication Data**

US 2014/0326208 A1 Nov. 6, 2014

(30) **Foreign Application Priority Data**

May 1, 2013 (JP) 2013-096248

(51) **Int. Cl.**

F02N 11/08 (2006.01)

F02N 11/10 (2006.01)

(52) **U.S. Cl.**

CPC ***F02N 11/0833*** (2013.01); ***F02N 11/0851*** (2013.01); ***F02N 11/101*** (2013.01); *F02N 11/0814* (2013.01); *F02N 2200/022* (2013.01); *F02N 2250/04* (2013.01)

(58) **Field of Classification Search**

CPC F02N 11/08; F02N 11/0833; F02N 11/04; F02N 11/0803; F02N 11/0814; F02N 11/0818; F02N 11/0825; F02N 11/0829; F02N 11/0837; F02N 11/084; F02N 11/0844; F02N 11/0848; F02N 11/0855; F02N 2200/021; F02N 2250/04; F02N 2250/06; F02N 2300/00; F02D 45/00

USPC 123/185.13, 179.1–179.24; 60/631, 60/39.13; 701/112–115

See application file for complete search history.

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(57) **ABSTRACT**

Provided are an internal combustion engine automatic stop/restart device and an internal combustion engine automatic stop/restart method capable of appropriately releasing a drive inhibition state of a starter (**200**) depending on an RPM of an internal combustion engine (**101**). The drive inhibition state of the starter is released when a drive inhibition release determination period, which is set depending on a time interval between a time point when a first reverse rotation crank signal is detected and a time point when a second reverse rotation crank signal is detected and a drive permission lower limit value corresponding period corresponding to a starter drivable RPM lower limit value, elapses before a third reverse rotation crank signal is input.

3 Claims, 9 Drawing Sheets

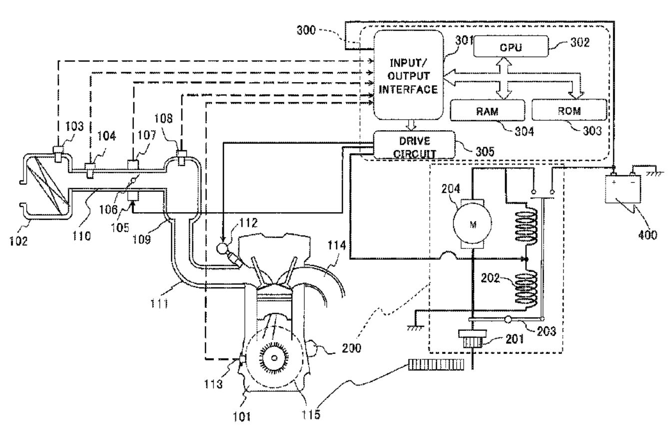

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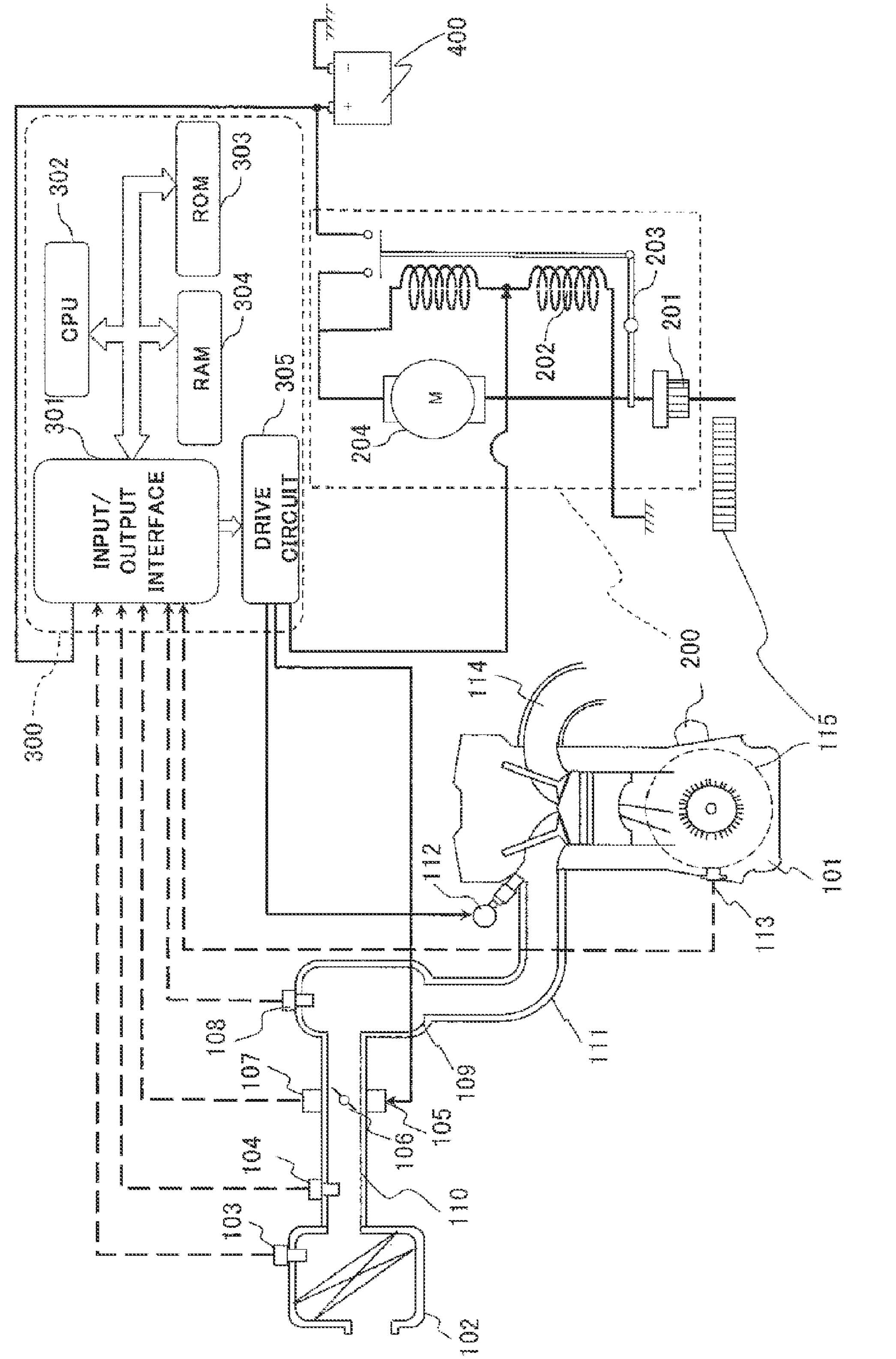
FIG. 1



400
+
−
302
CPU
303
ROM
304
RAM
305
301
INPUT/
OUTPUT
INTERFACE
DRIVE
CIRCUIT
203
201
202
M
204
300
114
200
115
112
113
101
111
108
109
107
105
106
104
110
103
102

FIG.2

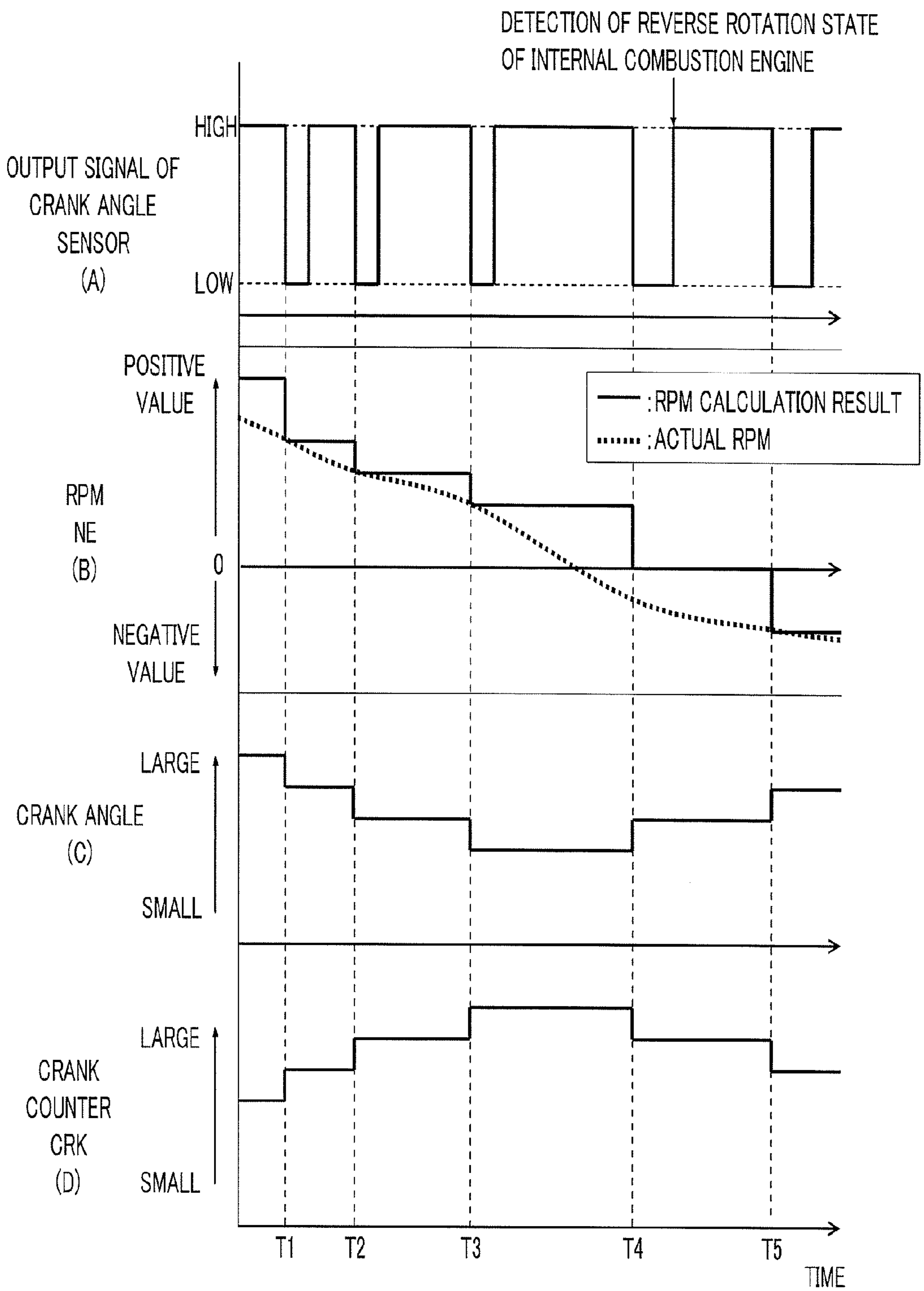

DETECTION OF REVERSE ROTATION STATE
OF INTERNAL COMBUSTION ENGINE
HIGH
LOW
OUTPUT SIGNAL OF
CRANK ANGLE
SENSOR
(A)
POSITIVE
VALUE
RPM
NE
(B)
0
NEGATIVE
VALUE
:RPM CALCULATION RESULT
:ACTUAL RPM
LARGE
CRANK ANGLE
(C)
SMALL
LARGE
CRANK
COUNTER
CRK
(D)
SMALL
T1
T2
T3
T4
T5
TIME

FIG.3

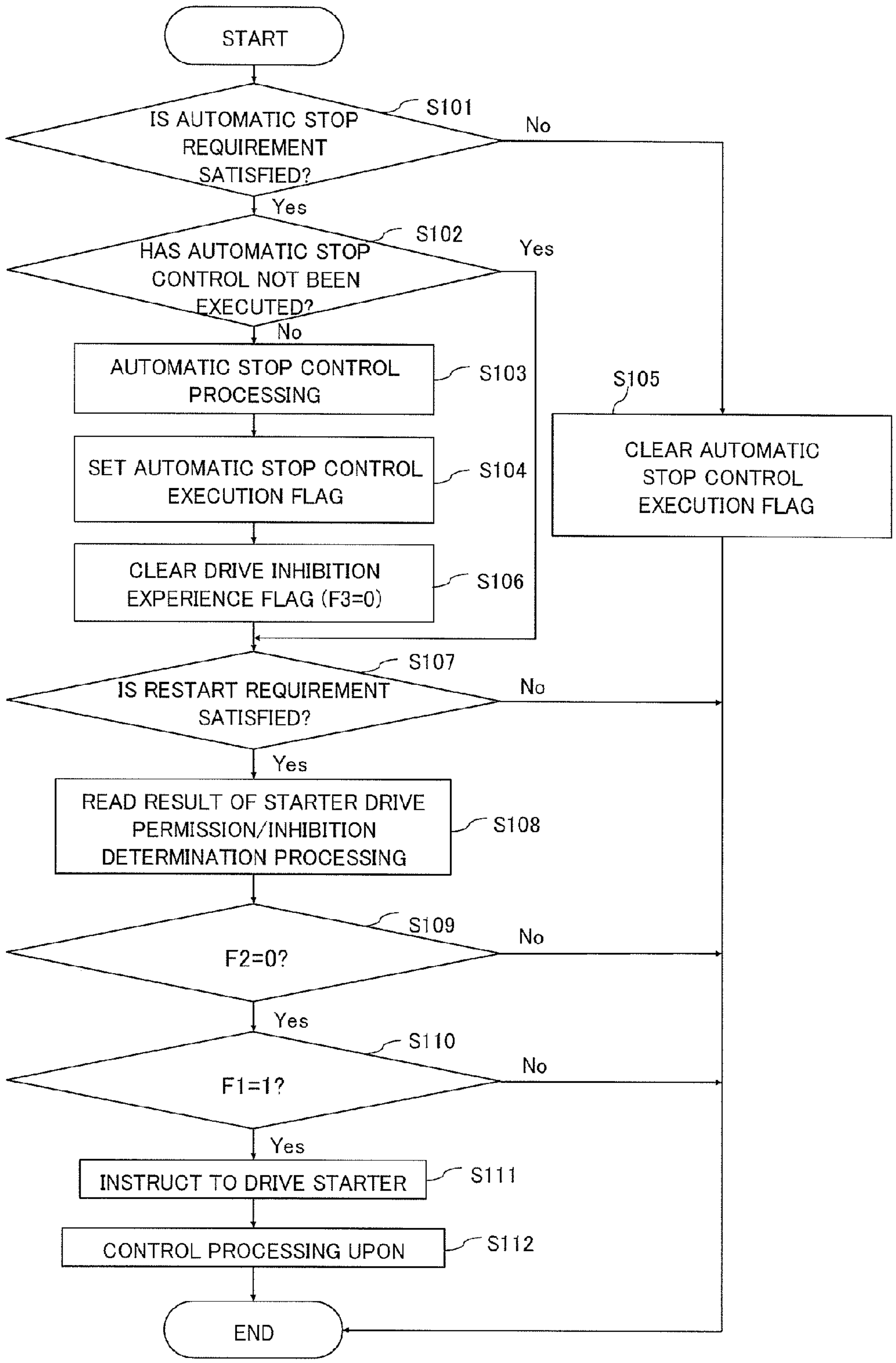

START
IS AUTOMATIC STOP REQUIREMENT SATISFIED?
S101
No
Yes
HAS AUTOMATIC STOP CONTROL NOT BEEN EXECUTED?
S102
Yes
No
AUTOMATIC STOP CONTROL PROCESSING
S103
SET AUTOMATIC STOP CONTROL EXECUTION FLAG
S104
CLEAR DRIVE INHIBITION EXPERIENCE FLAG (F3=0)
S106
S105
CLEAR AUTOMATIC STOP CONTROL EXECUTION FLAG
IS RESTART REQUIREMENT SATISFIED?
S107
No
Yes
READ RESULT OF STARTER DRIVE PERMISSION/INHIBITION DETERMINATION PROCESSING
S108
F2=0?
S109
No
Yes
F1=1?
S110
No
Yes
INSTRUCT TO DRIVE STARTER
S111
CONTROL PROCESSING UPON
S112
END

FIG.4A

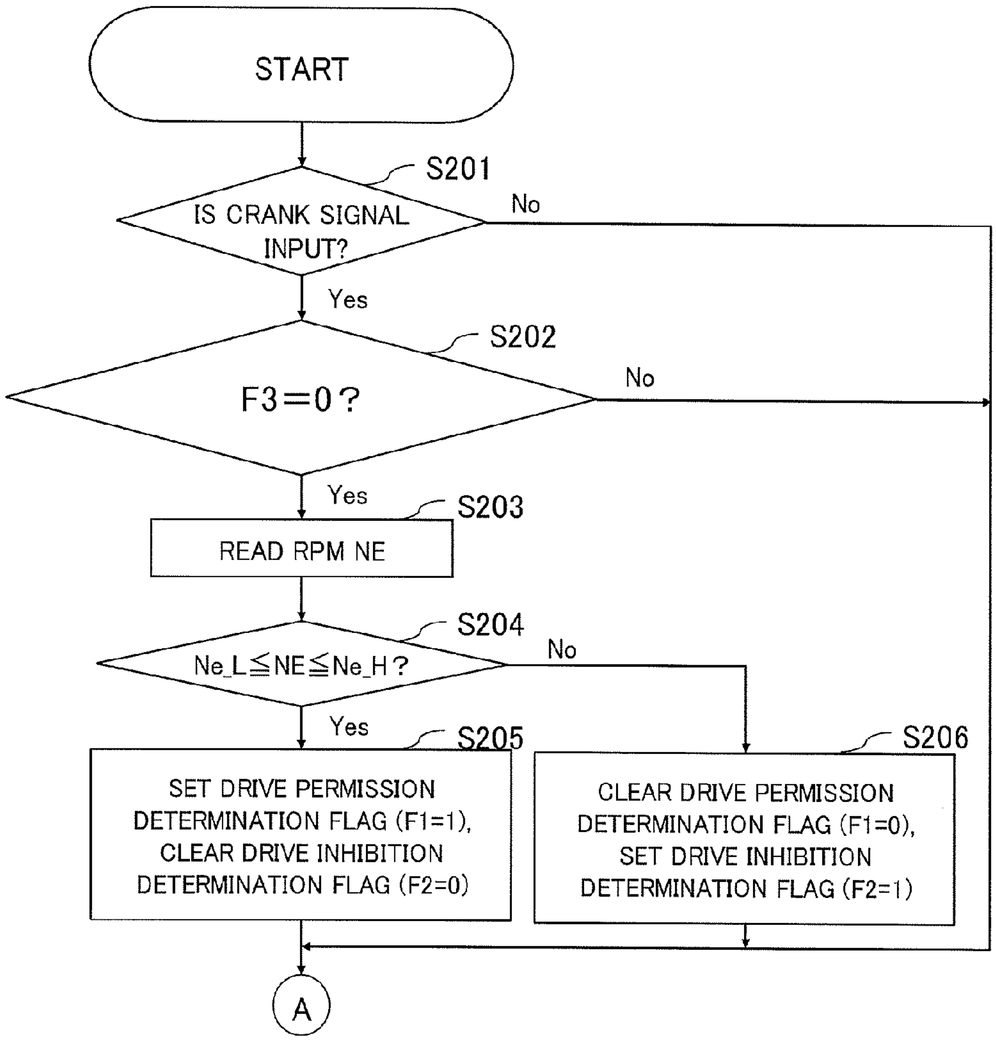

START
S201
IS CRANK SIGNAL INPUT?
No
Yes
S202
F3=0?
No
Yes
S203
READ RPM NE
S204
Ne_L≦NE≦Ne_H?
No
Yes
S205
SET DRIVE PERMISSION DETERMINATION FLAG (F1=1), CLEAR DRIVE INHIBITION DETERMINATION FLAG (F2=0)
S206
CLEAR DRIVE PERMISSION DETERMINATION FLAG (F1=0), SET DRIVE INHIBITION DETERMINATION FLAG (F2=1)
A

FIG.4B

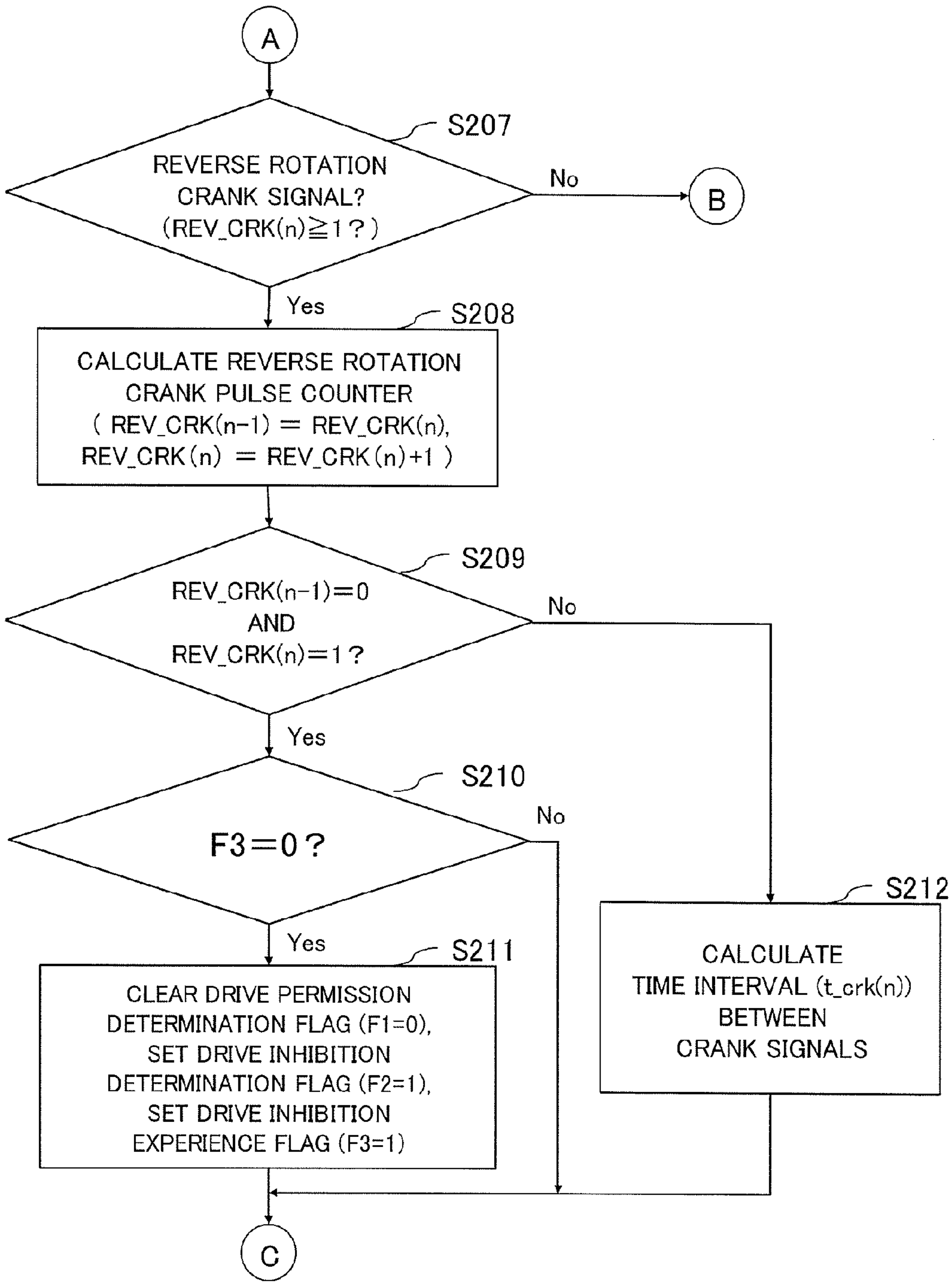

A
S207
REVERSE ROTATION CRANK SIGNAL? (REV_CRK(n)≧1 ?)
No
B
Yes
S208
CALCULATE REVERSE ROTATION CRANK PULSE COUNTER (REV_CRK(n-1) = REV_CRK(n), REV_CRK(n) = REV_CRK(n)+1)
S209
REV_CRK(n-1)=0 AND REV_CRK(n)=1 ?
No
Yes
S210
F3=0 ?
No
Yes
S211
CLEAR DRIVE PERMISSION DETERMINATION FLAG (F1=0), SET DRIVE INHIBITION DETERMINATION FLAG (F2=1), SET DRIVE INHIBITION EXPERIENCE FLAG (F3=1)
S212
CALCULATE TIME INTERVAL (t_crk(n)) BETWEEN CRANK SIGNALS
C

FIG.4C

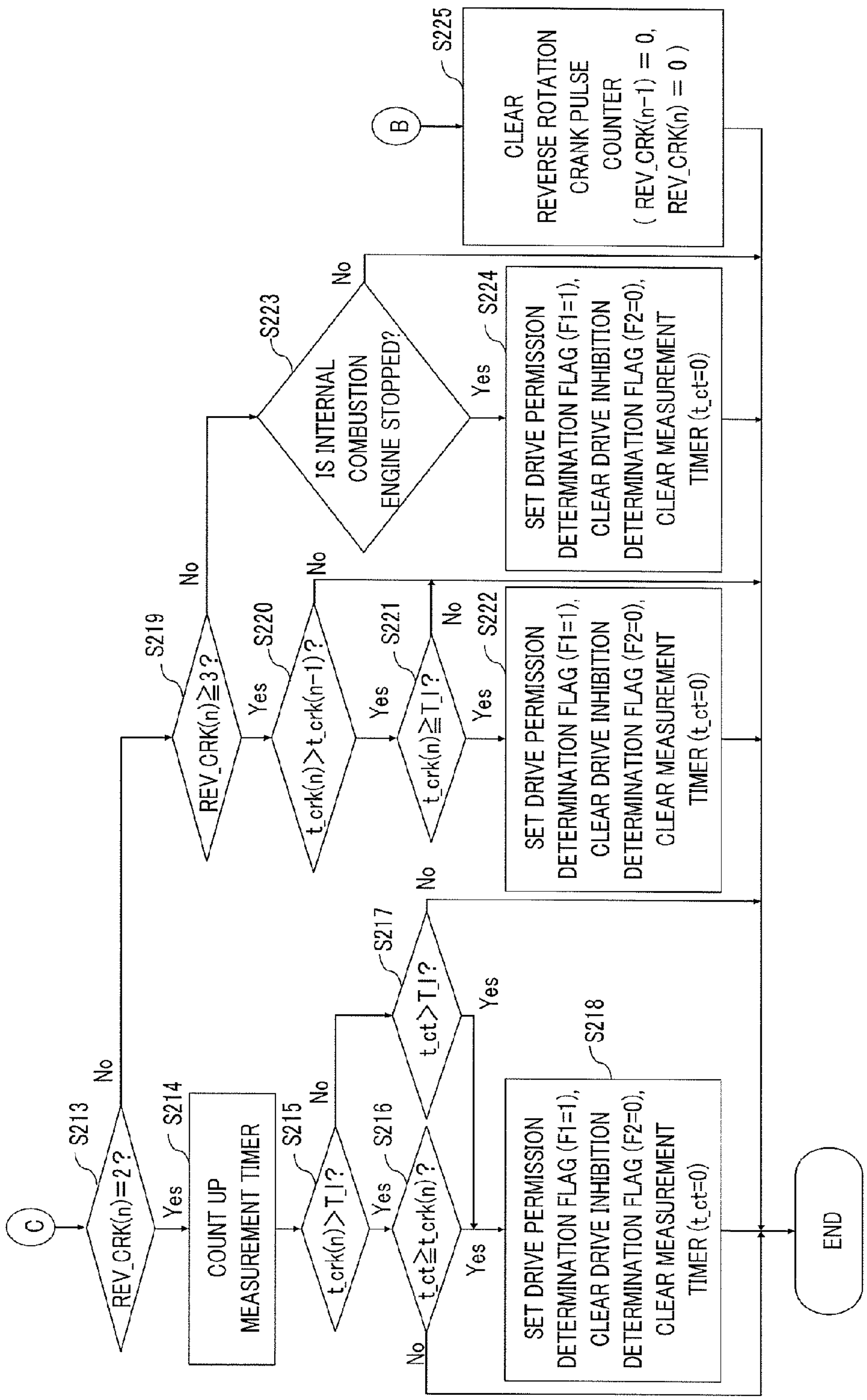
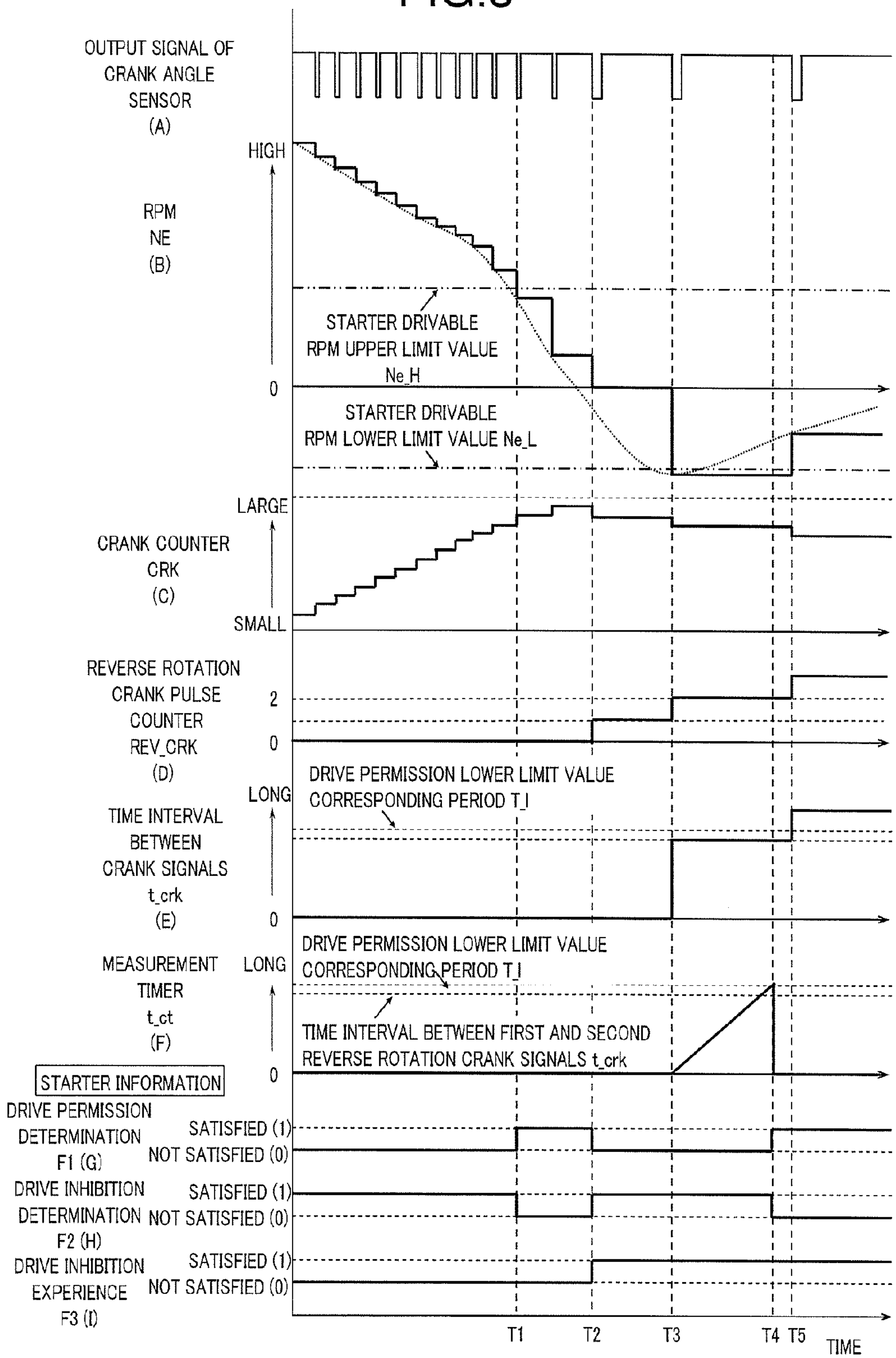

C
S213
REV_CRK(n)=2?
Yes
No
S214
COUNT UP MEASUREMENT TIMER
S215
t_crk(n)>T_l?
S216
t_ct≧t_crk(n)?
S217
t_ct>T_l?
S218
SET DRIVE PERMISSION DETERMINATION FLAG (F1=1), CLEAR DRIVE INHIBITION DETERMINATION FLAG (F2=0), CLEAR MEASUREMENT TIMER (t_ct=0)
S219
REV_CRK(n)≧3?
S220
t_crk(n)>t_crk(n-1)?
S221
t_crk(n)≧T_l?
S222
SET DRIVE PERMISSION DETERMINATION FLAG (F1=1), CLEAR DRIVE INHIBITION DETERMINATION FLAG (F2=0), CLEAR MEASUREMENT TIMER (t_ct=0)
S223
IS INTERNAL COMBUSTION ENGINE STOPPED?
S224
SET DRIVE PERMISSION DETERMINATION FLAG (F1=1), CLEAR DRIVE INHIBITION DETERMINATION FLAG (F2=0), CLEAR MEASUREMENT TIMER (t_ct=0)
B
S225
CLEAR REVERSE ROTATION CRANK PULSE COUNTER (REV_CRK(n-1) = 0, REV_CRK(n) = 0)
END

FIG.5



OUTPUT SIGNAL OF CRANK ANGLE SENSOR (A)
HIGH
RPM NE (B)
STARTER DRIVABLE RPM UPPER LIMIT VALUE Ne_H
0
STARTER DRIVABLE RPM LOWER LIMIT VALUE Ne_L
LARGE
CRANK COUNTER CRK (C)
SMALL
REVERSE ROTATION CRANK PULSE COUNTER REV_CRK (D)
2
0
DRIVE PERMISSION LOWER LIMIT VALUE CORRESPONDING PERIOD T_l
LONG
TIME INTERVAL BETWEEN CRANK SIGNALS t_crk (E)
0
DRIVE PERMISSION LOWER LIMIT VALUE CORRESPONDING PERIOD T_l
MEASUREMENT TIMER t_ct (F)
LONG
TIME INTERVAL BETWEEN FIRST AND SECOND REVERSE ROTATION CRANK SIGNALS t_crk
0
STARTER INFORMATION
DRIVE PERMISSION DETERMINATION F1 (G)
SATISFIED (1)
NOT SATISFIED (0)
DRIVE INHIBITION DETERMINATION F2 (H)
SATISFIED (1)
NOT SATISFIED (0)
DRIVE INHIBITION EXPERIENCE F3 (I)
SATISFIED (1)
NOT SATISFIED (0)
T1
T2
T3
T4
T5
TIME

FIG.6

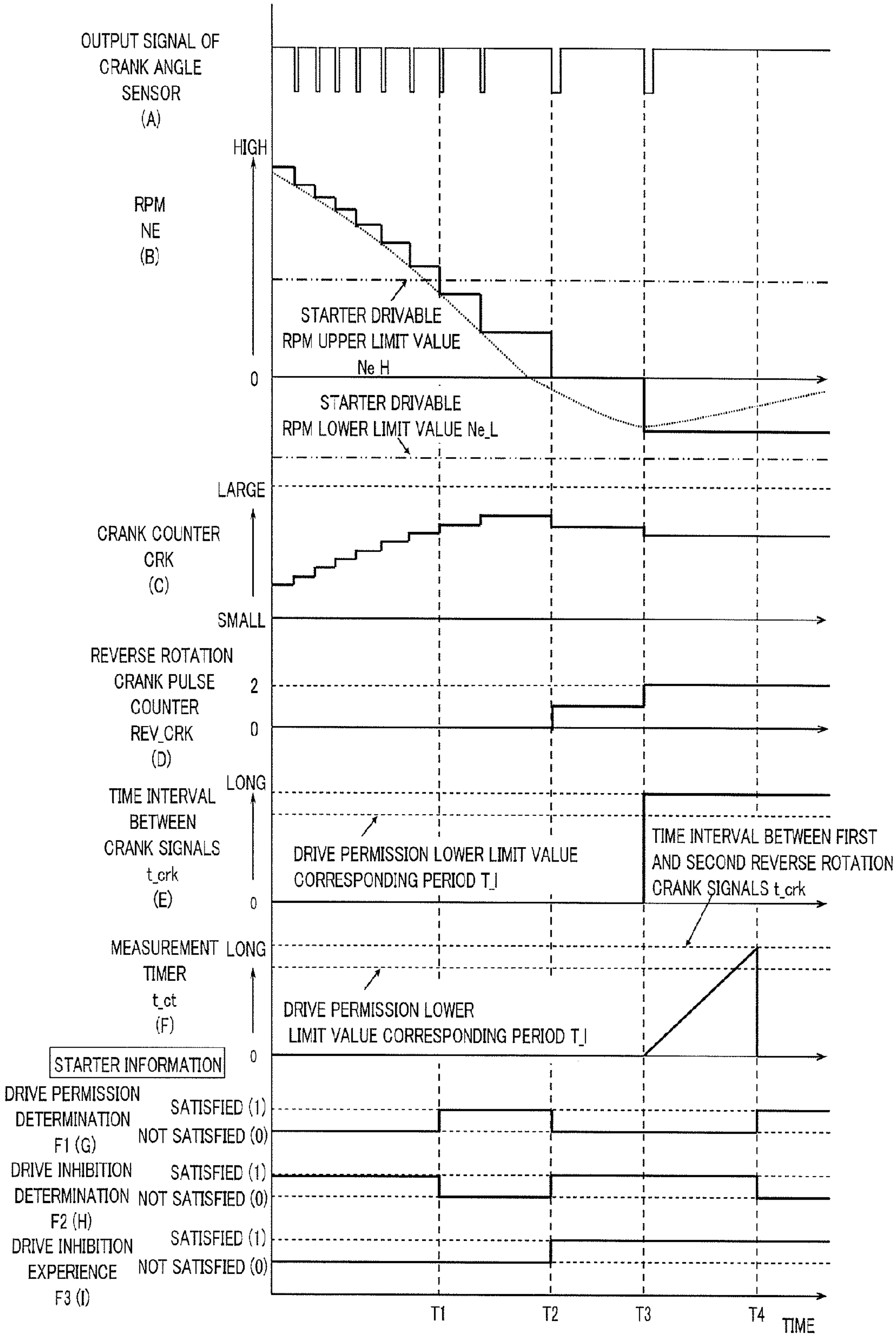
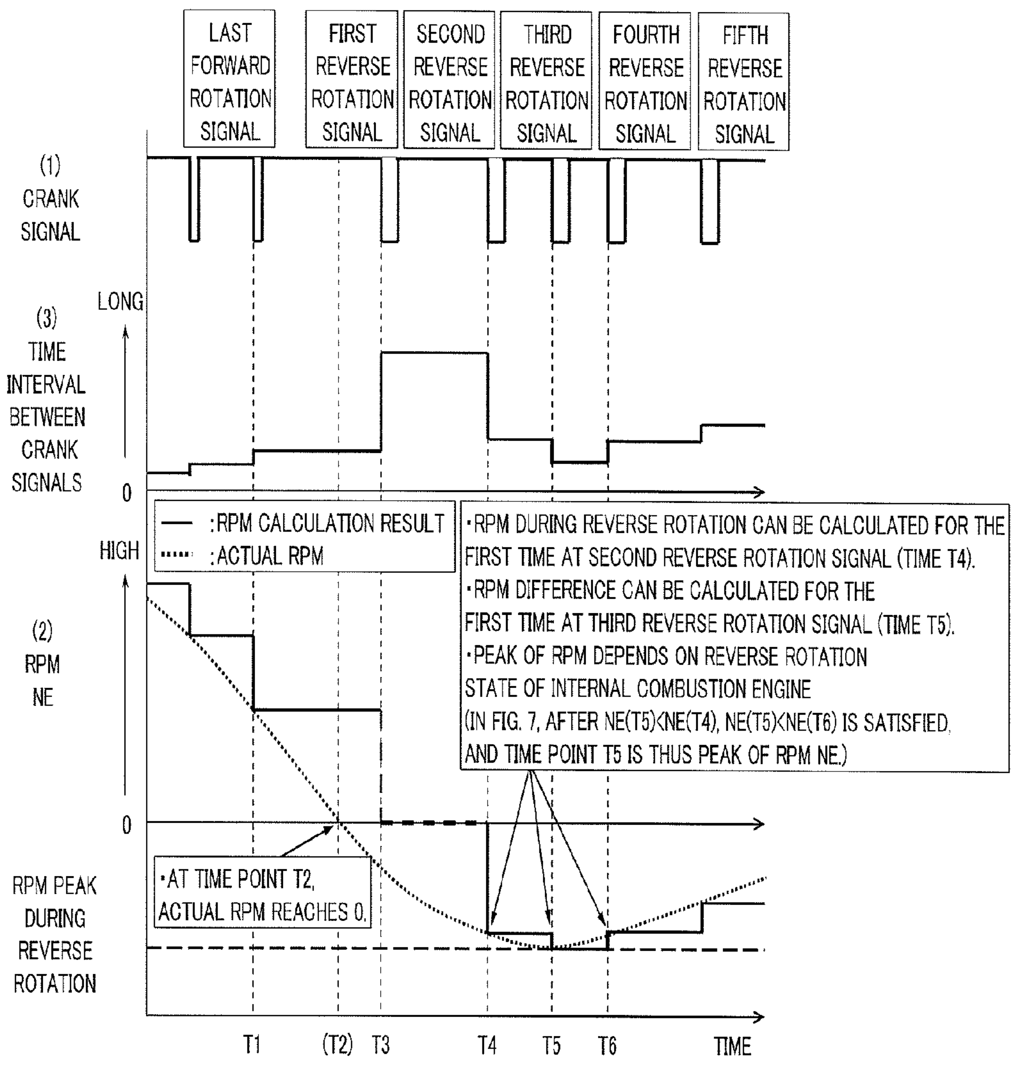

OUTPUT SIGNAL OF CRANK ANGLE SENSOR (A)
HIGH
RPM NE (B)
STARTER DRIVABLE RPM UPPER LIMIT VALUE Ne H
0
STARTER DRIVABLE RPM LOWER LIMIT VALUE Ne_L
LARGE
CRANK COUNTER CRK (C)
SMALL
REVERSE ROTATION CRANK PULSE COUNTER REV_CRK (D)
2
0
LONG
TIME INTERVAL BETWEEN CRANK SIGNALS t_crk (E)
DRIVE PERMISSION LOWER LIMIT VALUE CORRESPONDING PERIOD T_l
TIME INTERVAL BETWEEN FIRST AND SECOND REVERSE ROTATION CRANK SIGNALS t_crk
0
MEASUREMENT TIMER t_ct (F)
LONG
DRIVE PERMISSION LOWER LIMIT VALUE CORRESPONDING PERIOD T_l
0
STARTER INFORMATION
DRIVE PERMISSION DETERMINATION F1 (G)
SATISFIED (1)
NOT SATISFIED (0)
DRIVE INHIBITION DETERMINATION F2 (H)
SATISFIED (1)
NOT SATISFIED (0)
DRIVE INHIBITION EXPERIENCE F3 (I)
SATISFIED (1)
NOT SATISFIED (0)
T1
T2
T3
T4
TIME

FIG.7
PRIOR ART



INTERNAL COMBUSTION ENGINE AUTOMATIC STOP/RESTART DEVICE AND INTERNAL COMBUSTION ENGINE AUTOMATIC STOP/RESTART METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an internal combustion engine automatic stop/restart device and an internal combustion engine automatic stop/restart method for stopping an internal combustion engine when an automatic stop requirement is satisfied, and restarting the internal combustion engine when a restart requirement is satisfied.

2. Description of the Related Art

In recent years, an internal combustion engine automatic stop/restart device (namely, a device for carrying out so-called idling stop) in combination with an internal combustion engine is generally installed on a vehicle mainly in order to reduce a fuel consumption. Such an internal combustion engine automatic stop/restart device stops the internal combustion engine when a predetermined automatic stop requirement based on a deceleration or stop operation by a driver is satisfied, and restarts the internal combustion engine when a restart requirement based on a start or acceleration operation by the driver is satisfied.

Moreover, as an example of an operation of the internal combustion engine automatic stop/restart device, in order to prevent an excessive load from being applied to, for example, a starter or a power transmission system, when a rotation state of the automatically stopping internal combustion engine is a reverse rotation state, a drive inhibition state of the starter is set to inhibit the restart of the internal combustion engine, which is automatically stopping. Then, after an RPM peak of the internal combustion engine having the rotation state in the reverse rotation state is directly detected (after the RPM of the internal combustion engine takes the minimum value), when the RPM becomes equal to or more than a predetermined RPM, the drive inhibition state of the starter is released.

However, the conventional technology has the following problems.

According to the conventional technology, in order to detect the RPM peak of the internal combustion engine, it is necessary to detect a reverse rotation crank signal (reverse rotation crank angle) of the internal combustion engine at least three times. Therefore, if a period when the rotation state of the internal combustion engine is the reverse rotation state is short, and the reverse rotation crank signal can thus be detected, for example, only twice, the RPM peak cannot be detected.

In this case, there has been such a problem that the drive inhibition state of the starter cannot be appropriately released depending on the rotation state of the internal combustion engine. Moreover, as a result, the drive inhibition state of the starter cannot be released until the rotation of the internal combustion engine stops completely (for example, a period of approximately 200 milliseconds), and there has been such a problem that the period of the drive inhibition state can unnecessarily long.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-mentioned problems, and therefore has an object to provide an internal combustion engine automatic stop/restart device and an internal combustion engine automatic stop/restart method capable of properly releasing a drive inhibition state of a starter after an automatic stop requirement for an internal combustion engine is satisfied depending on a rotation state of the internal combustion engine, and restraining a period of the drive inhibition state of the starter to the minimum period.

There is provided an internal combustion engine automatic stop/restart device for stopping an internal combustion engine when an automatic stop requirement for automatically stopping the internal combustion engine is satisfied, and restarting the internal combustion engine when a restart requirement for restarting the internal combustion engine is satisfied after the automatic stop requirement is satisfied, the internal combustion engine automatic stop/restart device including: a starter for starting the internal combustion engine; an RPM calculation unit for calculating an RPM of the internal combustion engine based on a crank signal, which is an output signal of a crank angle detection unit for detecting a crank angle of the internal combustion engine; a rotation direction determination unit for determining whether the crank signal output by the crank angle detection unit is a forward rotation crank signal corresponding to a case where a rotation state of the internal combustion engine is a forward rotation state or a reverse rotation crank signal corresponding to a case where the rotation state is a reverse rotation state; a drive inhibition determination unit for bringing the starter into a drive inhibition state when the RPM calculated by the RPM calculation unit is not included in a drivable RPM range from a starter drivable RPM lower limit value to a starter drivable RPM upper limit value, which are prescribed in advance, and bringing the starter into the drive inhibition state when the crank signal output by the crank angle detection unit changes from the forward rotation crank signal to the reverse rotation crank signal; a drive inhibition release unit for calculating, when the crank angle detection unit outputs a second reverse rotation crank signal after outputting a first reverse rotation crank signal, which is a first reverse rotation crank signal when the forward rotation crank signal changes to the reverse rotation crank signal, a time interval between a first time point when the first reverse rotation crank signal is input and a second time point when the second reverse rotation crank signal is input, and releasing the drive inhibition state when a third reverse rotation crank signal is not input following the second reverse rotation crank signal until a drive inhibition release determination period set depending on the calculated time interval and a drive permission lower limit value corresponding period, which is a period acquired by converting the starter drivable RPM lower limit value, elapses from the second time point; and a restart control unit for driving the starter to restart the internal combustion engine when the restart requirement is satisfied and the starter is not in the drive inhibition state, in which when the time interval is shorter than the drive permission lower limit value corresponding period, the drive inhibition release unit sets the drive permission lower limit value corresponding period as the drive inhibition release determination period, and when the time interval is equal to or longer than the drive permission lower limit value corresponding period, the drive inhibition release unit sets the time interval as the drive inhibition release determination period.

There is provided an internal combustion engine automatic stop/restart method to be carried out by an engine control unit (ECU) in an internal combustion engine automatic stop/restart device including a starter for starting an internal combustion engine, the internal combustion engine automatic stop/restart method including: an automatic stop control step of stopping the internal combustion engine when an automatic stop requirement for automatically stopping the internal combustion engine is satisfied; an RPM calculation step of calculating an RPM of the internal combustion engine based on a crank signal, which is an output signal of a crank angle detection unit for detecting a crank angle of the internal combustion engine; a drive inhibition determination step of bringing the starter into a drive inhibition state when the RPM calculated in the RPM calculation step is not included in a drivable RPM range from a starter drivable RPM lower limit value to a starter drivable RPM upper limit value, which are prescribed in advance, and bringing the starter into the drive inhibition state when the crank signal output by the crank angle detection unit changes from a forward rotation crank signal to a reverse rotation crank signal; a drive inhibition release step of calculating, when the crank angle detection unit outputs a second reverse rotation crank signal after outputting a first reverse rotation crank signal, which is a first reverse rotation crank signal when the forward rotation crank signal changes to the reverse rotation crank signal, a time interval between a first time point when the first reverse rotation crank signal is input and a second time point when the second reverse rotation crank signal is input, and releasing the drive inhibition state when a third reverse rotation crank signal is not input following the second reverse rotation crank signal until a drive inhibition release determination period set depending on the calculated time interval and a drive permission lower limit value corresponding period, which is a period acquired by converting the starter drivable RPM lower limit value, elapses from the second time point; and a restart control step of driving the starter to restart the internal combustion engine when a restart requirement for restarting the internal combustion engine is satisfied after the automatic stop requirement is satisfied, and the starter is not in the drive inhibition state, in which the drive inhibition release step includes setting the drive permission lower limit value corresponding period as the drive inhibition release determination period when the time interval is shorter than the drive permission lower limit value corresponding period, and setting the time interval as the drive inhibition release determination period when the time interval is equal to or longer than the drive permission lower limit value corresponding period.

According to the present invention, the drive inhibition state of the starter is released when the drive inhibition release determination period set depending on the time interval between the time point when the first reverse rotation crank signal is detected and the time point when the second reverse rotation crank signal is detected and the drive permission lower limit value corresponding period corresponding to the starter drivable RPM lower limit value elapses before the third reverse rotation crank signal is input. It is thus possible to provide the internal combustion engine automatic stop/restart device and the internal combustion engine automatic stop/restart method capable of properly releasing the drive inhibition state of the starter after the automatic stop requirement for the internal combustion engine is satisfied depending on the rotation state of the internal combustion engine, and restraining the period of the drive inhibition state of the starter to the minimum period.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a configuration diagram illustrating a schematic configuration of an internal combustion engine automatic stop/restart device according to a first embodiment of the present invention;

FIG. **2** is an explanatory diagram in a case where a crank angle, a crank counter, and an RPM of an engine are calculated based on an output signal of a crank angle sensor according to the first embodiment of the present invention;

FIG. **3** is a flowchart illustrating automatic stop/restart processing for the engine executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention;

FIG. **4**A is a flowchart illustrating drive permission/drive inhibition determination processing for a starter executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention;

FIG. **4**B is a flowchart illustrating the drive permission/drive inhibition determination processing for the starter executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention;

FIG. **4**C is a flowchart illustrating the drive permission/drive inhibition determination processing for the starter executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention;

FIG. **5** is an explanatory diagram showing an example of operations carried out at respective time points by the internal combustion engine automatic stop/restart device according to the first embodiment;

FIG. **6** is an explanatory diagram showing another example of operations carried out at respective time points by the internal combustion engine automatic stop/restart device according to the first embodiment; and

FIG. **7** is an explanatory diagram in a case where an internal combustion engine automatic stop/restart device according to a conventional technology detects an RPM peak when a rotation state of an internal combustion engine is a reverse rotation state.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A description is now given of an internal combustion engine automatic stop/restart device and an internal combustion engine automatic stop/restart method according to a preferred embodiment of the present invention referring to the drawings. Note that, like components are denoted by like reference symbols, and overlapping descriptions thereof are omitted in descriptions of the drawings.

First Embodiment

Referring to FIG. **7**, first, in order to clearly describe technical features of the present invention, a detailed description is given of the above-mentioned problems of the conventional technology. FIG. **7** is an explanatory diagram of a case where the internal combustion engine automatic stop/restart device according to the conventional technology detects an RPM peak when a rotation state of an internal combustion engine is a reverse rotation state.

FIG. **7** shows temporal changes in crank signals (1), an RPM NE (2), and a time interval between crank signals (3). Note that, regarding illustration of the RPM NE (2), a solid line represents a calculated RPM NE (RPM calculation result) and a dotted line represents an actual RPM of the internal combustion engine. Moreover, the RPM during the reverse rotation of the internal combustion engine is represented by a negative number for the sake of convenience.

On this occasion, the RPM NE of the internal combustion engine is generally calculated from a time interval between predetermined crank angles (such as 60 degrees before the top dead center) or a time interval corresponding to a crank angle (such as 30 degrees). However, in a case where the rotation state of the internal combustion engine changes such as a case where the internal combustion engine starts rotating or a case where the rotation changes from the forward rotation to the reverse rotation, a time point when the change in rotation state occurs cannot be determined by detecting the crank angle.

Thus, a time point when a first reverse rotation crank signal which is detected for the first time after the change in rotation state occurs is detected (a time point when a first reverse rotation crank angle is detected) is assumed as a start time point of the change in rotation state. Specifically, when the rotation of the internal combustion engine changes from the forward rotation to the reverse rotation, a reverse rotation start time point corresponds to a time point when the first reverse rotation crank signal is detected. Moreover, in this case, a reverse rotation crank signal is detected for the first time, and the RPM NE of the internal combustion engine corresponding to the time point when the reverse rotation crank signal is detected cannot thus be calculated.

Moreover, if the rotation state (RPM) of the internal combustion engine exhibits, for example, a behavior exemplified in FIG. **7**, detection of the reverse rotation crank signal twice enables calculation of the RPM during the reverse rotation for the first time. Specifically, at a time point T4, the RPM during the reverse rotation can be calculated for the first time. Note that, at a time point T3 when the reverse rotation crank signal is detected for the first time, for the sake of convenience, the RPM NE is set to 0 (Note that, the actual RPM of the internal combustion engine becomes 0 at a time point T2).

Moreover, if the reverse rotation crank signal is detected three times, an RPM difference can be calculated for the first time. Specifically, at a time point T5, the RPM difference can be calculated for the first time.

Thus, the internal combustion engine automatic stop/restart device according to the conventional technology detects the RPM peak during the reverse rotation by calculating the RPM after the time point when the second reverse rotation crank signal is detected.

Specifically, in accordance with respective magnitudes of RPMs NE(T4), NE(T5), and NE(T6) calculated at respective time points T4, T5, and T6, the RPM NE(T5) is detected as the RPM peak. Then, after the RPM peak is detected, a drive inhibition state of a starter is released, and if a restart requirement is satisfied, the internal combustion engine restarts.

However, when the RPM peak is thus detected during the reverse rotation, as described above, the period in which the rotation state of the internal combustion engine is the reverse rotation state is short, and, for example, the reverse rotation crank signal can be detected only twice. As a result, in this case, the drive inhibition state of the starter cannot be appropriately released in accordance with the rotation state of the internal combustion engine.

In contrast, the present invention has a technical feature in that the drive inhibition state of a starter **200** is released when a drive inhibition release determination period set in accordance with a time interval between a time point when a first reverse rotation crank signal is detected and a time point when a second reverse rotation crank signal is detected and a drive permission lower limit value corresponding period corresponding to a starter drivable RPM lower limit value has elapsed before a third reverse rotation crank signal is input. As a result, the drive inhibition state of the starter can be appropriately released in accordance with the rotation state of the internal combustion engine.

Referring to FIG. **1**, a description is now given of the internal combustion engine automatic stop/restart device according to a first embodiment of the present invention. FIG. **1** is a configuration diagram illustrating a schematic configuration of the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention. Note that, in FIG. **1**, in addition to the internal combustion engine automatic stop/restart device, an internal combustion engine **101** and its peripheral components are illustrated.

First, a description is given of the internal combustion engine **101** (hereinafter referred to as "engine **101**"), to which the internal combustion engine automatic stop/restart device according to the first embodiment is applied, by way of specific examples. Note that, the configuration, the operation, and the like of the engine **101** are not limited to details described below, and the present invention can be applied to types of engine other than the exemplified engine **101**.

As illustrated in FIG. **1**, through an air filter **102**, an intake pipe **110**, a surge tank **109**, and an intake manifold **111**, air is supplied to each of cylinders of the engine **101**.

On the air filter **102**, an intake air temperature sensor **103** for detecting the temperature of intake air is provided. Moreover, on the intake pipe **110**, an air flow sensor **104** for detecting an air amount of the intake air, a throttle valve **106** for controlling a flow rate of the intake air, and a throttle opening sensor **107** for detecting an opening of the throttle valve **106** are provided. Note that, the throttle valve **106** is located downstream of the intake pipe **110** with respect to the air flow sensor **104**, and is operated by the drive of a motor **105**. Moreover, on the surge tank **109**, an intake pipe pressure sensor **108** for detecting an intake air pressure in the tank is provided.

A fuel injection valve **112** provided close to an intake port of each of the cylinders of the engine **101** supplies the engine **101** with a fuel. The supplied fuel is mixed with the supplied air to form an air-fuel mixture, and the air-fuel mixture is taken into a combustion chamber of each of the cylinders of the engine **101**. Moreover, the air-fuel mixture taken into the combustion chamber is combusted by being ignited by an ignition plug (not shown). Then, a combustion gas generated by the combustion passes through an exhaust pipe **114**, and, after toxic gases are purified by a catalyst device (not shown), is exhausted to the atmosphere.

Moreover, in the engine **101**, a water temperature sensor (not shown) for detecting a cooling water temperature of the engine **101** and a crank angle sensor **113** for detecting the crank angle of the engine **101** are provided. Note that, the crank angle sensor **113** according to the first embodiment is a specific example of a crank angle detection unit for detecting the crank angle of the engine **101**.

A description is now given of the internal combustion engine automatic stop/restart device according to the first embodiment. The internal combustion engine automatic stop/restart device includes the starter **200** and an engine control unit **300** (hereinafter referred to as "ECU **300**").

The starter **200** includes a pinion gear **201**, a solenoid **202**, a plunger **203**, and a starter motor **204**. Moreover, the starter motor **204** is connected to a battery **400** via a wire having a contact which is turned on by an operation of the plunger **203**.

On this occasion, the starter **200** and a ring gear **115** coupled to a crankshaft of the engine **101** are provided in the engine **101**. Then, when the engine **101** is started or restarted, the engine **101** is cranked by the starter **200** and the ring gear **115**.

Specifically, when the engine **101** starts or restarts, power supply to the solenoid **202** starts based on a drive signal output by the ECU **300** described later, and a motion of the plunger **203** starts to push the pinion gear **201**. Then, after the pinion gear **201** and the ring gear **115** come into abutment against each other, the contact on the wire between the battery **400** and the starter motor **204** turns on to start rotational drive of the starter motor **204**. Then, the pinion gear **201** and the ring gear **115** securely mesh with each other, and the cranking of the engine **101** starts.

Moreover, the ECU **300** described later calculates the crank angle, a crank counter CRK, the RPM NE of the engine **101**, and the like based on the output signal of the crank angle sensor **113** provided to the engine **101**.

The ECU **300** includes an input/output interface **301**, a CPU (microprocessor) **302**, a read only memory (ROM) **303**, a random access memory (RAM) **304**, and a drive circuit **305**.

The output signals from the above-mentioned various sensors, and detection signals such as a depressed amount of an accelerator pedal (not shown) and a depressed amount of a brake (not shown) are input to the input/output interface **301**.

The CPU **302** reads a control program and various constants stored in the ROM **303** described later, carries out control calculation, and outputs a calculation (determination) result to the RAM **304** and the input/output interface **301** described later.

Moreover, the CPU **302** determines whether or not an automatic stop requirement and a restart requirement according to the present invention are satisfied, and carries out control calculation (such as the calculation of the RPM NE of the engine **101**) based on the output signal from the crank angle sensor **113**.

In the ROM **303**, the control program, the various constants, and the like used by the CPU **302** for calculation are stored. Moreover, in the RAM **304**, the calculation result by the CPU **302** is temporarily stored. Moreover, the drive circuit **305** outputs drive signals to the fuel injection valve **112**, the starter **200**, and the like based on the calculation result input from the CPU **302**.

Referring to FIG. **2**, a description is now given of the crank angle, the crank counter CRK, and the RPM NE of the engine **101** calculated by the ECU **300** based on the output signal of the crank angle sensor **113**. FIG. **2** is an explanatory diagram of a case where the crank angle, the crank counter CRK, and the RPM NE of the engine **101** are calculated based on the output signal of the crank angle sensor **113** according to the first embodiment of the present invention.

FIG. **2** shows temporal changes in the output signal (A) of the crank angle sensor **113**, the RPM NE (B), the crank angle (C), and the crank counter CRK (D). Note that, regarding illustration of the RPM NE (B), a solid line represents the calculated RPM NE (RPM calculation result) by the ECU **300** and a dotted line represents the actual RPM of the internal combustion engine. Moreover, the RPM during the reverse rotation of the internal combustion engine is represented by a negative number for the sake of convenience.

On this occasion, the output signal of the crank angle sensor **113** according to the first embodiment changes depending on whether the rotation state of the engine **101** is the forward rotation state or the reverse rotation state. Thus, the rotation state of the engine **101** can be accurately detected. Moreover, the various calculated values calculated by the ECU **300** based on the output signal of the crank angle sensor **113** behave as shown in FIG. **2**.

Moreover, each time the output signal of the crank angle sensor **113** is input to the ECU **300**, the RPM NE of the engine **101** and the like are calculated. Specifically, the calculation of the RPM NE of the engine **101**, the crank angle, and the crank counter CRK is carried out at a fall time point (a time point at a change from a HIGH value to a LOW value) of the output signal of the crank angle sensor **113**.

It is determined that, if a LOW period which is a total period when the output signal of the crank angle sensor **113** can take the LOW value in each cycle is short, the rotation state of the engine **101** is the forward rotation state, and if the LOW period is long, the rotation state of the engine **101** is the reverse rotation state. Moreover, the output signal of the crank angle sensor **113** is output at each predetermined angle (such as ten degrees) between crank angles. The determination of the rotation state of the engine **101** is carried out by a rotation direction determination unit stored in the ROM **303** in the ECU **300**. In other words, the rotation direction determination unit determines whether the crank signal output by the crank angle sensor **113** is a forward rotation crank signal corresponding to a case where the rotation state of the engine **101** is the forward rotation state or the reverse rotation crank signal corresponding to a case where the rotation state is the reverse rotation state.

Moreover, the RPM NE of the engine **101** is calculated from Equation (1) below by using a time interval between a currently-input time point (T(n)) which is a time point when the output signal of the crank angle sensor **113** is currently input and a previously-input time point (T(n−1)) which is a time point when the output signal is previously input, and the predetermined angle (such as ten degrees) between the crank angles. The calculation of the RPM NE of the engine **101** is carried out by an RPM calculation unit stored in the ROM **303** in the ECU **300**.

$$RPMNE[r/min]=60/(T(n)-T(n-1))\times(\text{predetermined angle between crank angles})/360 \quad (1)$$

Moreover, the crank angle is calculated so that the compression top dead center of each of the cylinders of the engine **101** is assumed as a reference (0 degrees), and the crank angle takes a maximum value after the compression top dead center.

Moreover, the crank counter CRK is incremented until the crankshaft of the engine **101** rotates twice (intake, compression, combustion, and exhaust strokes). In other words, the crank counter CRK is calculated so as to take the maximum value before the top dead center in the compression stroke after two rotations, and to return to zero at the top dead center when the top dead center in the compression stroke of a first cylinder of the engine **101** is assumed as a reference (=0).

As shown in FIG. **2**, the ECU **300** determines that the rotation state of the engine **101** is the forward rotation state based on the output signal of the crank angle sensor **113** (hereinafter referred to "crank signal" as needed) in a period from the time point T1 to the time point T3. Moreover, the time interval between the crank signals of the forward rotation crank signals (crank signals corresponding to the forward rotation) output by the crank angle sensor **113** gradually extends from the time point T1 to the time point T3, and the RPM NE of the engine **101** thus decreases. Moreover, the crank angle is subtracted by the predetermined angle each time, and the crank counter CRK is added by a predetermined value each time.

After the time point T4, the LOW period in the output signal of the crank angle sensor **113** extends, and the ECU **300** thus determines that the rotation state of the engine **101** is the reverse rotation state. Moreover, the output signal of the crank angle sensor **113** detected at the time point T4 is the first reverse rotation crank signal (a crank signal corresponding to the first reverse rotation), and the RPM NE of the engine **101** is thus set to 0. Similarly, the crank angle is added by the predetermined angle, and the crank counter CRK is subtracted by the predetermined value.

Note that, a reason for assuming the RPM NE of the engine **101** as 0 at the time point T4 is as described below. Specifically, the rotation state of the engine **101** is the reverse rotation state at the time point T4, and hence the RPM NE actually needs to be not zero but a negative value.

However, the rotation state of the engine **101** changes from the forward rotation state to the reverse rotation state in the period from the time point T3 to the time point T4, and thus, as shown in FIG. **2**, the actual RPM becomes 0 temporarily. Moreover, the crank angle sensor **113** outputs the signal in accordance with the rotation state of the crankshaft, and cannot output the signal in a state where the actual RPM is zero. Thus, a time point when the actual RPM is 0 cannot be determined based on the output signal of the crank angle sensor **113**, and thus the time point T4 is assumed as the start time point of the reverse rotation of the engine **101**, and the RPM NE is set to 0.

When the second reverse rotation crank signal is output from the crank angle sensor **113** at the time point T5, a negative RPM NE (namely, the RPM NE when the rotation state of the engine **101** is the reverse rotation state) is calculated for the first time. Moreover, the crank angle is added by the predetermined angle, and the crank counter CRK is subtracted by the predetermined value.

After the rotation state of the engine **101** changes from the reverse rotation state to the forward rotation state, when the crank angle sensor **113** outputs an output signal corresponding to a first forward rotation, similarly, the RPM NE of the engine **101** is assumed to be 0. Moreover, the crank angle is subtracted by the predetermined angle, and the crank counter CRK is added by the predetermined value.

In this way, the ECU **300** accurately determines the rotation state of the engine **101** based on the output signal of the crank angle sensor **113**, and even when the rotation state changes, the crank angle of the engine **101** and the crank counter CRK can be accurately calculated.

Referring to flowcharts of FIGS. **3** and **4**A to **4**C, a description is now given of a series of an operation procedure of the internal combustion engine automatic stop/restart device according to the first embodiment. FIG. **3** is a flowchart illustrating automatic stop/restart processing for the engine **101** that is executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention. FIGS. **4**A to **4**C are flowcharts illustrating drive permission/drive inhibition determination processing for the starter **200** that is executed by the internal combustion engine automatic stop/restart device according to the first embodiment of the present invention. It should be noted that FIGS. **4**A to **4**C are one flowchart, which is divided on three drawing sheets, and hence a portion illustrated in FIG. **4**A, a portion illustrated in FIG. **4**B, and a portion illustrated in FIG. **4**C are continuous.

First, a description is given of the flowchart of FIG. **3**. A series of processing in the flowchart of FIG. **3** is calculated (executed) by the ECU **300** in the internal combustion engine automatic stop/restart device for each processing cycle (such as 10 millisecond cycle).

First, in Step S**101**, the ECU **300** determines whether or not the automatic stop requirement is satisfied. Specifically, it is determined whether or not the automatic stop requirement is satisfied based on various types of information for determining an intention of a driver to decelerate or stop.

Specific examples of the above-mentioned various types of information include (1) whether or not a detected temperature of the water temperature sensor is equal to or more than a predetermined temperature (such as 60 degrees), (2) whether or not a vehicle speed equal to or higher than a predetermined speed (such as 12 km/h) has been detected once or more, (3) whether or not a current vehicle speed is equal to or less than a predetermined speed (such as 0 km/h), (4) whether or not a brake pedal is depressed, and (5) whether or not the depressed amount of the accelerator pedal is equal to or less than a predetermine value (such as no depressed amount).

Then, if the ECU **300** determines in Step S**101** that the automatic stop requirement is not satisfied (namely, No), the ECU **300** proceeds to Step S**105**, clears an automatic stop control execution flag described later, finishes the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**101** that the automatic stop requirement is satisfied (namely, Yes), the ECU **300** proceeds to Step S**102**, and determines whether or not the automatic stop control has not been executed. Specifically, it is determined whether or not the automatic stop control has not been executed based on whether or not the automatic stop control execution flag described later is set.

Then, if the ECU **300** determines in Step S**102** that the automatic stop control has not been executed (namely, No), the ECU **300** proceeds to Step S**103**, and executes automatic stop control processing. Specifically, in Step S**103**, the ECU **300** stops the drive signal to the fuel injection valve **112**, and stops the fuel supply to the engine **101**. Moreover, the ECU **300**, for example, additionally carries out control such as a change in a control amount of the throttle valve **106** and release of a clutch of a transmission mounted to the engine **101**.

Then, in Step S**104**, the ECU **300** sets the automatic stop control execution flag, and proceeds to Step S**106**. Then, in Step S**106**, the ECU **300** clears a drive inhibition experience flag F3 (F3=0), and proceeds to Step S**107**. A detailed description is later given of the drive inhibition experience flag F3.

On the other hand, if the ECU **300** determines in Step S**102** that the automatic stop control has been executed (namely, Yes), the ECU **300** proceeds to Step S**107**. Specifically, if the ECU **300** executes the processing in Step S**102** for the first time after the automatic stop requirement is satisfied, the ECU **300** has not executed the automatic stop control yet. Thus, the ECU **300** determines in Step S**102** that the automatic stop control has not been executed, and proceeds to Step S**103**.

Moreover, if the ECU **300** executes the processing in Step S**102** for the second or subsequent time after the automatic stop requirement is satisfied, the ECU **300** has already executed the automatic stop control. Thus, the ECU **300** determines in Step S**102** that the automatic stop control has been carried out, and proceeds to Step S**107**.

Then, in Step S**107**, the ECU **300** determines whether or not the restart requirement is satisfied. Specifically, it is determined whether or not the restart requirement is satisfied based on various types of information for determining an intention of the driver of a start or acceleration operation, information indicating a state of the battery **400** for supplying electric power to various types of sensor such as the intake air temperature sensor **103** provided to the engine **101** and the like, and other such information.

Specific examples of the above-mentioned various types of information include (1) whether or not the depressed amount of the brake pedal is equal to or less than a predetermined value (such as no depressed amount), and (2) whether or not the depressed amount of the accelerator pedal is equal to or more than a predetermined value (such as a depressed amount of equal to or more than 10% of the depressed amount).

Then, if the ECU **300** determines in Step S**107** that the restart requirement is not satisfied (namely, No), the ECU **300** stops the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**107** that the restart requirement is satisfied (namely, Yes), the ECU **300** proceeds to Step S**108**. Then, in Step S**108**, the ECU **300** reads a result of the drive permission/drive inhibition determination processing for the starter **200**, and proceeds to Step S**109**. Note that, a detailed description is later given of the drive permission/drive inhibition determination processing for the starter **200**.

Then, in Step S**109**, the ECU **300** determines whether or not a drive inhibition determination flag F2 read in Step S**108** is "0". Then, if the ECU **300** determines in Step S**109** that the drive inhibition determination flag F2 is "1" (namely, No), the ECU **300** stops the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**109** that the drive inhibition determination flag F2 is "0" (namely, Yes), the ECU **300** proceeds to Step S**110**.

Then, in Step S**110**, the ECU **300** determines whether or not a drive permission determination flag F1 read in Step S**108** is "1". Then, if the ECU **300** determines in Step S**110** that the drive permission determination flag F1 is "0" (namely, No), the ECU **300** stops the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**110** that the drive permission determination flag F1 is "1" (namely, Yes), the ECU **300** proceeds to Step S**111**.

Then, in Step S**111**, the starter **200** is in a drivable state, and hence the ECU **300** issues a drive instruction to the starter **200** to start the cranking of the engine **101**, and proceeds to Step S**112**.

Then, in Step S**112**, the ECU **300** executes control processing upon restart, finishes the series of processing, and proceeds to next processing. Specifically, the ECU **300** outputs the drive signal to the fuel injection valve **112** to restart the fuel injection in Step S**112**. Further, the ECU **300** executes, for example, control to change the control amount of the throttle valve **106** to a control amount for the restart.

The processing in Steps S**101** to S**106** is executed by an automatic stop control unit stored in the ROM **303** in the ECU **300**. Moreover, the processing in Steps S**107** to S**112** is executed by a restart control unit stored in the ROM **303** in the ECU **300**.

A description is now given of the flowcharts of FIGS. **4**A to **4**C. A series of processing in the flowcharts of FIGS. **4**A to **4**C is calculated (executed) by the ECU **300** in the internal combustion engine automatic stop/restart device for each processing cycle (such as 2.5 millisecond cycle) shorter than a processing cycle of the flowchart of FIG. **3** above.

Moreover, as described above, a result (calculation result) of the drive permission/drive inhibition determination processing for the starter **200** is read in the case where Step S**108** is carried out for processing in the flowchart of FIG. **3** above. Further, as described below, processing in Steps S**201** to S**206** corresponds to processing for drive permission determination for the starter **200**, and processing in Steps S**207** to S**225** corresponds to processing for drive inhibition determination and processing for drive inhibition release for the starter **200**.

First, in Step S**201**, the ECU **300** determines whether or not the crank signal is input from the crank angle sensor **113**. Then, if the ECU **300** determines in Step S**201** that the crank signal is not input (namely, No), the ECU **300** proceeds to Step S**207**.

On the other hand, if the ECU **300** determines in Step S**201** that the crank signal is input (namely, Yes), the ECU **300** proceeds to Step S**202**, and determines whether or not the drive inhibition experience flag F3 is "0". Note that, the drive inhibition experience flag F3 is a flag to be set only if the drive inhibition determination flag F2 is set after the reverse rotation crank signal is input, and is information used to make the drive inhibition determination only once during the reverse rotation of the engine **101**.

Then, if the ECU **300** determines in Step S**202** that the drive inhibition experience flag F3 is "1" (namely, No), the ECU **300** proceeds to Step S**207**. On the other hand, if the ECU **300** determines in Step S**202** that the drive inhibition experience flag F3 is "0" (namely, Yes), the ECU **300** proceeds to Step S**203**. Note that, the drive inhibition experience flag F3 is "0" during the forward rotation of the engine **101**.

Then, in Step S**203**, the ECU **300** reads the RPM NE of the engine **101**, proceeds to S**204**, and makes drive permission determination for the starter **200**. Specifically, the ECU **300** determines whether or not the RPM NE of the engine **101** is included in a drivable RPM range from a starter drivable RPM lower limit value Ne_L (such as −60 r/min) to a starter drivable RPM upper limit value Ne_H (such as 80 r/min) of the starter **200**.

On this occasion, as described above, in the starter **200**, when the pinion gear **201** meshes with the ring gear **115** and the contact is turned on, the power supply to the starter motor **204** starts and the rotational drive starts. Therefore, when the engine **101** is started or restarted, the pinion gear **201** of the starter **200** meshes with the ring gear **115** of the engine **101** in a non-rotation state. Moreover, it is difficult for the pinion gear **201** to mesh with the ring gear **115** depending on the RPM NE of the engine **101**. Thus, in Step S**204**, it is determined whether or not the RPM NE of the engine **101** is included in the drivable RPM range in which the pinion gear **201** can mesh with the ring gear **115**.

Moreover, the ring gear **115** of the engine **101** is coupled to the crankshaft of the engine **101**, and the RPM of the ring gear **115** is thus equal to the RPM NE of the engine **101**. Therefore, based on the RPM NE of the engine **101**, the drive permission determination for the starter **200** is made.

Then, if the ECU **300** determines in Step S**204** that the RPM NE of the engine **101** is included in the drivable RPM range (namely, Yes), the ECU **300** proceeds to Step S**205**. Then, in Step S**205**, the ECU **300** sets the drive permission determination flag F1 (F1=1), simultaneously clears the drive inhibition determination flag F2 (F2=0), and proceeds to Step S**207**. Note that, in the first embodiment, setting a flag means setting "1" to the flag, and clearing a flag means setting "0" to the flag.

On the other hand, if the ECU **300** determines in Step S**204** that the RPM NE of the engine **101** is not included in the drivable RPM range (namely, No), the ECU **300** proceeds to Step S**206**. Then, in Step S**206**, the ECU **300** clears the drive permission determination flag F1 (F1=0), simultaneously sets the drive inhibition determination flag F2 (F2=1), and proceeds to Step S**207**.

Then, in Step S**207**, the ECU **300** determines whether or not the input crank signal is the reverse rotation crank signal.

Note that, the ECU **300** may determine whether or not the input crank signal is the reverse rotation crank signal by determining whether or not a reverse rotation crank pulse counter REV_CRK(n) is equal to or more than 1. In other words, if the reverse rotation crank pulse counter REV_CRK (n) is equal to or more than 1, the input crank signal is determined to be the reverse rotation crank signal. Moreover, if the reverse rotation crank pulse counter REV_CRK(n) is 0, the input crank signal is determined to be the forward rotation crank signal.

On this occasion, the reverse rotation crank pulse counter REV_CRK(n) is information which has 0 as an initial value, and is counted up for the first time when the reverse rotation crank signal is input. Moreover, when the rotation state of the engine **101** is the forward rotation state (in other words, when the input crank signal is determined not to be the reverse rotation crank signal), the reverse rotation crank pulse counter REV_CRK(n) is not counted up.

Then, if the ECU **300** determines in Step S**207** that the input crank signal is not the reverse rotation crank signal (namely, No), the ECU **300** proceeds to Step S**225**. Moreover, in Step S**225**, the ECU **300** clears the reverse rotation crank pulse counter REV_CRK(n−1) at last processing and the reverse rotation crank pulse counter REV_CRK(n) at the current processing to set both thereof to zero, finishes the series of processing, and proceeds to next processing.

Note that, the reverse rotation crank pulse counter REV_CRK(n) at the current processing is hereinafter simply referred to as "reverse rotation crank pulse counter REV_CRK(n)", and the reverse rotation crank pulse counter REV_CRK(n−1) at the last processing is hereinafter simply referred to as "reverse rotation crank pulse counter REV_CRK(n−1)". On the other hand, if the ECU **300** determines in Step S**207** that the input crank signal is the reverse rotation crank signal (namely, Yes), the ECU **300** proceeds to Step S**208**.

Then, in Step S**208**, the ECU **300** carries out calculation for the reverse rotation crank pulse counter REV_CRK(n), and proceeds to Step S**209**. Specifically, the ECU **300** replaces the reverse rotation crank pulse counter REV_CRK(n−1) by the reverse rotation crank pulse counter REV_CRK(n) (REV_CRK(n−1)=REV_CRK(n)). Further, the ECU **300** counts up the reverse rotation crank pulse counter REV_CRK (n) by 1 (REV_CRK(n)=REV_CRK(n)+1)).

Then, in Step S**209**, the ECU **300** determines whether or not the input crank signal is a first reverse rotation crank signal. Specifically, if the reverse rotation crank pulse counter REV_CRK(n−1) is 0 and the reverse rotation crank pulse counter REV_CRK(n) is 1, the ECU **300** determines that the input crank signal is the first reverse rotation crank signal. On the other hand, if the reverse rotation crank pulse counter REV_CRK(n−1) is not 0, or the reverse rotation crank pulse counter REV_CRK(n) is not 1, the ECU **300** determines that the input crank signal is not the first reverse rotation crank signal.

Then, if the ECU **300** determines in Step S**209** that the input crank signal is not the first reverse rotation crank signal (namely, No), the ECU **300** proceeds to Step S**212**. Note that, if a second or subsequent reverse rotation crank signal is input, the input crank signal is determined not to be the first reverse rotation crank signal.

Then, in Step S**212**, the ECU **300** calculates a time interval t_crk(n) between the crank signals based on an input time point when the last reverse rotation crank signal is input and an input time point when the second last reverse rotation crank signal is input, and proceeds to Step S**213**. Note that, as described above, the time point when the first reverse rotation crank signal is input is a reverse rotation start time point, and hence when the second reverse rotation crank signal is input, the time interval t_crk(n) between the crank signals is calculated for the first time.

On the other hand, if the ECU **300** determines in Step S**209** that the input crank signal is the first reverse rotation crank signal (namely, Yes), the ECU **300** proceeds to Step S**210**, and determines whether or not the drive inhibition experience flag F3 is "0".

Then, if the ECU **300** determines in Step S**210** that the drive inhibition experience flag F3 is "1" (namely, No), the ECU **300** proceeds to Step S**213**. Specifically, if the reverse rotation crank pulse counter REV_CRK(n) is 1, and the calculation in Step S**210** is carried out for the second or subsequent times, the drive inhibition experience flag F3 is "1".

On the other hand, if the ECU **300** determines in Step S**210** that the drive inhibition experience flag F3 is "0" (namely, Yes), the ECU **300** proceeds to Step S**211**. Specifically, if the calculation in Step S**210** is carried out for the first time (in other words, if the input crank signal is the first reverse rotation crank signal), the drive inhibition experience flag F3 is "0".

Then, in Step S**211**, the ECU **300** clears the drive permission determination flag F1 (F1=0), sets the drive inhibition determination flag F2 (F2=1), sets the drive inhibition experience flag F3 (F3=1), and proceeds to Step S**213**.

Then, in Step S**213**, the ECU **300** determines whether or not the reverse rotation crank pulse counter REV_CRK(n) is 2. Then, if the ECU **300** determines in Step S**213** that the reverse rotation crank pulse counter REV_CRK(n) is not 2 (namely, No), the ECU **300** proceeds to Step S**219**.

Specifically, if the input crank signal is the first reverse rotation crank signal, the reverse rotation crank pulse counter REV_CRK(n) is 1, and the reverse rotation crank pulse counter REV_CRK(n) is thus determined not to be 2.

On the other hand, if the ECU **300** determines in Step S**213** that the reverse rotation crank pulse counter REV_CRK(n) is 2 (namely, Yes), the ECU **300** proceeds to Step S**214**.

Specifically, if the input crank signal is the second reverse rotation crank signal, the reverse rotation crank pulse counter REV_CRK(n) is 2, and the reverse rotation crank pulse counter REV_CRK(n) is thus determined to be 2.

Then, in Step S**214**, the ECU **300** counts up a measurement timer, and proceeds to Step S**215**. Note that, the measurement timer is a timer counted up after the second reverse rotation crank signal is input, and, specifically, measures an elapsed time t_ct from the time point when the second reverse rotation crank signal is input. Note that, the elapsed time t_ct from the time point when the second reverse rotation crank signal is input measured by the measurement timer is hereinafter referred to as "timer-measured period t_ct".

Then, in Step S**215**, the ECU **300** determines whether or not the time interval t_crk(n) between the crank signals calculated in Step S**212** is longer than a drive permission lower limit value corresponding period T_l.

Note that, the drive permission lower limit value corresponding period T_l is set based on the drivable RPM of the starter **200**, and is stored in the ROM **303** of the ECU **300** in advance. Specifically, the drive permission lower limit value corresponding period T_l is set, by using a rotation angle (predetermined angle between crank angles) for each crank signal, from a value in time converted from the drivable RPM of the starter **200**. For example, when the starter drivable RPM lower limit value Ne_L of the starter **200** is −60 r/min, and the rotation angle for each crank signal is 10 degrees, the drive permission lower limit value corresponding period T_l is approximately 28 milliseconds.

Then, if the ECU **300** determines in Step S**215** that the time interval t_crk(n) between the crank signals is longer than the drive permission lower limit value corresponding period T_l (namely, Yes), the ECU **300** proceeds to Step S**216**.

Then, in Step S**216**, the ECU **300** determines whether or not the timer-measured period t_ct is equal to or longer than the time interval t_crk(n) between the crank signals.

Then, if the ECU **300** determines in Step S**216** that the timer-measured period t_ct is equal to or longer than the time interval t_crk(n) between the crank signals (namely, Yes), the ECU **300** proceeds to Step S**218**. On the other hand, if the ECU **300** determines in Step S**216** that the timer-measured period t_ct is shorter than the time interval t_crk(n) between the crank signals (namely, No), the ECU **300** finishes the series of processing, and proceeds to next processing.

Moreover, if the ECU **300** determines in Step S**215** that the time interval t_crk(n) between the crank signals is equal to or shorter than the drive permission lower limit value corresponding period T_l (namely, No), the ECU **300** proceeds to Step S**217**.

Then, in Step S**217**, the ECU **300** determines whether or not the timer-measured period t_ct is longer than the drive permission lower limit value corresponding period T_l.

Then, if the ECU **300** determines in Step S**217** that the timer-measured period t_ct is longer than the drive permission lower limit value corresponding period T_l (namely, Yes), the ECU **300** proceeds to Step S**218**. On the other hand, if the ECU **300** determines in Step S**217** that the timer-measured period t_ct is equal to or shorter than the drive permission lower limit value corresponding period T_l (namely, No), the ECU **300** finishes the series of processing, and proceeds to next processing.

Then, in Step S**218**, the ECU **300** sets the drive permission determination flag F1 (F1=1), clears the drive inhibition determination flag F2 (F2=0), clears the measurement timer (t_ct=0), finishes the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**213** that the reverse rotation crank pulse counter REV_CRK(n) is not 2 (namely, No), the ECU **300** proceeds to Step S**219**, and determines whether or not the reverse rotation crank pulse counter REV_CRK(n) is equal to or more than 3. Then, if the ECU **300** determines in Step S**219** that the reverse rotation crank pulse counter REV_CRK(n) is equal to or more than 3 (namely, Yes), the ECU **300** proceeds to Step S**220**.

Then, in Step S**220**, the ECU **300** determines whether or not the time interval t_crk(n) between the crank signals is longer than a time interval t_crk(n−1) between the crank signals. Note that, the time interval t_crk(n−1) between the crank signals is a time interval calculated last time before the time interval t_crk(n) between the crank signals is calculated.

Then, if the ECU **300** determines in Step S**220** that the time interval t_crk(n) between the crank signals is equal to or shorter than the time interval t_crk(n−1) between the crank signals (namely, No), the ECU **300** finishes the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**220** that the time interval t_crk(n) between the crank signals is longer than the time interval t_crk(n−1) between the crank signals (namely, Yes), the ECU **300** proceeds to Step S**221**.

Then, in Step S**221**, the ECU **300** determines whether or not the time interval t_crk(n) between the crank signals is equal to or longer than the drive permission lower limit value corresponding period T_l. Then, if the ECU **300** determines in Step S**221** that the time interval t_crk(n) between the crank signals is shorter than the drive permission lower limit value corresponding period T_l (namely, No), the ECU **300** finishes the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**221** that the time interval t_crk(n) between the crank signals is equal to or longer than the drive permission lower limit value corresponding period T_l (namely, Yes), the ECU **300** proceeds to Step S**222**.

Then, in Step S**222**, the ECU **300** sets the drive permission determination flag F1 (F1=1), clears the drive inhibition determination flag F2 (F2=0), clears the measurement timer (t_ct=0), finishes the series of processing, and proceeds to next processing.

On the other hand, if the ECU **300** determines in Step S**219** that the reverse rotation crank pulse counter REV_CRK(n) is less than 3 (namely, No), the ECU **300** proceeds to Step S**223**, and determines whether or not the internal combustion engine (engine **101**) is stopped. Specifically, if the reverse rotation crank pulse counter REV_CRK(n) is 1 (in other words, if the input crank signal is the first reverse rotation crank signal), Step S**223** is carried out.

Then, if the ECU **300** determines in Step S**223** that the engine **101** is not stopped (namely, No), the ECU **300** finishes the series of processing, and proceeds to next processing. Note that, in this case, the drive inhibition state of the starter **200** continues.

On the other hand, if the ECU **300** determines in Step S**223** that the engine **101** is stopped (namely, Yes), the ECU **300** proceeds to Step S**224**.

Then, in Step S**224**, the ECU **300** sets the drive permission determination flag F1 (F1=1), clears the drive inhibition determination flag F2 (F2=0), clears the measurement timer (t_ct=0), finishes the series of processing, and proceeds to next processing.

Note that, the processing in Steps S**201** to S**206** is executed by a drive permission determination unit stored in the ROM **303** in the ECU **300**. Moreover, the processing in Steps S**207** to S**211** is executed by a drive inhibition determination unit stored in the ROM **303** in the ECU **300**. Further, the processing in Steps S**212** to S**225** is executed by a drive inhibition release unit stored in the ROM **303** in the ECU **300**.

Then, referring to timing charts of FIGS. **5** and **6**, a description is given of operations carried out at respective time points by the internal combustion engine automatic stop/restart device according to the first embodiment. FIG. **5** is an explanatory diagram showing an example of operations carried out at respective time points by the internal combustion engine automatic stop/restart device according to the first embodiment. FIG. **6** is an explanatory diagram showing another example of operations carried out at respective time points by the internal combustion engine automatic stop/restart device according to the first embodiment.

Note that, FIGS. **5** and **6** mainly show, particularly, the operation of releasing the drive inhibition state carried out for the engine **101** by the internal combustion engine automatic stop/restart device according to the first embodiment while the RPM NE of the engine **101** is decreasing during the automatic stop.

FIGS. **5** and **6** show temporal changes of the output signal of the crank angle sensor **113** (A), the RPM NE (B), the crank counter CRK (C), the reverse rotation crank pulse counter REV_CRK (D), the time interval t_crk between the crank signals (E), the timer-measured period t_ct by the measurement timer (F), the drive permission determination flag F1 (G), the drive inhibition determination flag F2 (H), and the drive inhibition experience flag F3 (I).

Note that, regarding the representation of the RPM NE (B), the solid line represents the calculated RPM NE (RPM calculation result) by the ECU **300** and the dotted line represents the actual RPM of the internal combustion engine. Moreover, the RPM during the reverse rotation of the internal combustion engine is represented by a negative value for the sake of convenience.

On this occasion, as described above, the output signal of the crank angle sensor **113** changes depending on whether the rotation state of the engine **101** is the forward rotation state or the reverse rotation state. Therefore, the various calculated values calculated by the ECU **300** behave as shown in FIGS. **5** and **6** based on the output signal of the crank angle sensor **113**.

First, a description is given of the timing chart of FIG. **5**. As shown in FIG. **5**, before a time point T1, as time approaches the time point T1, a time interval between the crank signals on the output signal of the crank angle sensor **113** increases.

In this case, the RPM NE of the engine **101** decreases depending on the time interval, and simultaneously, the crank counter CRK is added by the predetermined value. Moreover, the rotation state of the engine **101** is the forward rotation state, and the RPM NE is not included in the drivable RPM range of the starter **200**. Thus, the drive permission determination flag F1 becomes "0" and the drive inhibition determination flag F2 becomes "1", and the starter **200** is thus brought into the drive inhibition state. Moreover, the reverse rotation crank pulse counter REV_CRK and the like do not change.

At the time point T1, the RPM NE of the engine **101** reaches an RPM equal to or less than the starter drivable RPM upper limit value Ne_H. In this case, the drive permission determination flag F1 becomes "1" and the drive inhibition determination flag F2 becomes "0", and the starter **200** is thus brought into the drive permission state. When the starter **200** is brought into the drive permission state and the restart requirement is simultaneously satisfied, the starter **200** carries out the driving.

At a time point T2, the output signal of the crank angle sensor **113** becomes the first reverse rotation crank signal. In this case, the crank counter CRK is subtracted by the predetermined value, and simultaneously, the reverse rotation crank pulse counter REV_CRK (D) is counted up from 0 to 1. Moreover, the drive permission determination flag F1 becomes "0" the drive inhibition determination flag F2 becomes "1", and the starter **200** is thus brought into the drive inhibition state. Moreover, the drive inhibition experience flag F3 becomes "1". As shown in FIG. **5**, after the time point T2 when the output signal of the crank angle sensor **113** becomes the first reverse rotation crank signal, the starter **200** is in the drive inhibition state.

At a time point T3, the output signal of the crank angle sensor **113** becomes the second reverse rotation crank signal. In this case, the crank counter CRK is subtracted by the predetermined value, and simultaneously, the reverse rotation crank pulse counter REV_CRK is counted up from 1 to 2. Moreover, the time interval t_crk (hereinafter referred to as "time interval t_crk(1,2)") between the crank signals, which are the first reverse rotation crank signal and the second reverse rotation crank signal, is calculated, and simultaneously, the count up of the measurement timer starts.

On this occasion, at the time point T3 when the second reverse rotation crank signal is input, the time interval t_crk (1,2) is calculated, and is compared in magnitude with the drive permission lower limit value corresponding period T_l as described above. Then, the drive inhibition release determination period is determined depending on the comparison result. Note that, in FIG. **5**, the time interval t_crk(1,2) is shorter than the drive permission lower limit value corresponding period T_l, and the drive inhibition release determination period thus corresponds to the drive permission lower limit value corresponding period T_l.

At a time point T4, the elapsed time t_ct from the time point T3 measured by the measurement timer becomes equal to or longer than the drive permission lower limit value corresponding period T_l, which is the drive inhibition release determination period. In this case, the drive permission determination flag F1 becomes "1" and the drive inhibition determination flag F2 becomes "0", and the starter **200** is thus brought into the drive permission state. In other words, at the time point T4 earlier than a time point T5 when the third reverse rotation crank signal is input, the drive inhibition state of the starter **200** is released. Moreover, the measurement timer is cleared (t_ct=0).

Note that, after the time point T4 when the drive inhibition release determination period has elapsed from the time point T3, the starter **200** is again brought into the drive permission state, and the starter **200** carries out the driving when the above-mentioned restart requirement is satisfied.

As described above, FIG. **5** exemplifies a case where the RPM NE at the time point T3 when the second reverse rotation crank signal is input is higher than the starter drivable RPM lower limit value Ne_L.

On this occasion, if the third reverse rotation crank signal is input before the drive permission lower limit value corresponding period T_l elapses from the input of the second reverse rotation crank signal, the engine **101** is reversely rotated, and the actual RPM of the engine **101** is higher than the starter drivable RPM lower limit value Ne_L. In this case, the actual RPM of the engine **101** is not included in the drivable RPM range, and the drive inhibition state of the starter **200** is thus not released.

In contrast, if the third reverse rotation crank signal is not input before the drive permission lower limit value corresponding period T_l elapses from the input of the second reverse rotation crank signal, the engine **101** is reversely rotated, and the actual RPM of the engine **101** is lower than the starter drivable RPM lower limit value Ne_L when the drive permission lower limit value corresponding period T_l elapses. In this case, the actual RPM of the engine **101** has passed the RPM peak, and is included in the drivable RPM range, and the drive inhibition state of the starter **200** is thus released.

As described above, in this case, the ECU **300** can release the drive inhibition state of the starter **200** without detecting the RPM peak based on the calculation result of the RPM NE of the engine **101** at the time point T4, which is different from the conventional technology. In other words, the ECU **300** can appropriately release the drive inhibition state of the starter **200** only based on the two inputs of the reverse rotation crank signal depending on the rotation state of the engine **101**.

A description is now given of the timing chart of FIG. **6**. Note that, in FIG. **6**, an operation in the period from a time point before the time point T1 to the time point T3 is the same as the operation described above referring to FIG. **5**, and a description thereof is therefore omitted.

At the time point T3, the output signal of the crank angle sensor **113** becomes the second reverse rotation crank signal. In this case, the crank counter CRK is subtracted by the predetermined value, and simultaneously, the reverse rotation crank pulse counter REV_CRK is counted up from 1 to 2. Moreover, the time interval t_crk between the crank signals is calculated, and simultaneously, the count up of the measurement timer starts.

On this occasion, at the time point T3 when the second reverse rotation crank signal is input, the time interval t_crk (1,2) is calculated, and is compared in magnitude with the drive permission lower limit value corresponding period T_l as described above. Then, the drive inhibition release determination period is determined depending on the comparison result. Note that, in FIG. **6**, unlike in FIG. **5**, the time interval t_crk(1,2) is equal to or longer than the drive permission lower limit value corresponding period T_l, and the drive inhibition release determination period thus corresponds to the time interval t_crk(1,2).

At the time point T4, the elapsed time t_ct from the time point T3 measured by the measurement timer becomes equal to or longer than the time interval t_crk(1,2), which is the drive inhibition release determination period. In this case, the drive permission determination flag F1 becomes "1" and drive inhibition determination flag F2 becomes "0", and the starter **200** is thus brought into the drive permission state. In other words, at the time point T4 earlier than the time point when the third reverse rotation crank signal is input, the drive inhibition state of the starter **200** is released. Moreover, the measurement timer is cleared (t_ct=0).

Note that, after the time point T4 when the drive inhibition release determination period has elapsed from the time point T3, the starter **200** is again brought into the drive permission state, and the starter **200** carries out the driving when the above-mentioned restart requirement is satisfied.

As described above, FIG. **6** exemplifies a case where the RPM NE at the time point T3 when the second reverse rotation crank signal is input is lower than the starter drivable RPM lower limit value Ne_L.

On this occasion, if the third reverse rotation crank signal is input before the time interval t_crk(1,2) elapses from the input of the second reverse rotation crank signal, the engine **101** is reversely rotated, and the actual RPM of the engine **101** is higher than the RPM NE at the time point T3. In this case, the actual RPM of the engine **101** does not reach the RPM peak, and the drive inhibition state of the starter **200** is thus not released.

In contrast, if the third reverse rotation crank signal is not input before the time interval t_crk(1,2) elapses from the input of the second reverse rotation crank signal, the engine **101** is reversely rotated, and the actual RPM of the engine **101** is lower than the RPM NE at the time point T3 when the time interval t_crk(1,2) elapses. In this case, the actual RPM of the engine **101** has passed the RPM peak, and the drive inhibition state of the starter **200** is thus released.

As described above, the ECU **300** can release the drive inhibition state of the starter **200** without detecting the RPM peak based on the calculation of the RPM NE of the engine **101** at the time point when the third reverse rotation crank signal is input, which is different from the conventional technology. In other words, the ECU **300** can appropriately release the drive inhibition state of the starter **200** only based on the two inputs of the reverse rotation crank signal depending on the rotation state of the engine **101**.

In this way, the ECU **300** can release the drive inhibition state of the starter **200** when the drive inhibition release determination period set depending on the time interval t_crk between the crank signals (time interval between the time point T2 and the time point T3), which are the first reverse rotation crank signal and the second reverse rotation crank signal, and the drive permission lower limit value corresponding period T_l corresponding to the starter drivable RPM lower limit value Ne_L elapses before the third reverse rotation crank signal is input.

As a result, the drive inhibition state of the starter **200** can quickly be released depending on the rotation state after the engine **101** enters the reverse rotation state.

Moreover, if the time interval t_crk between the crank signals, which are the first reverse rotation crank signal and the second reverse rotation crank signal, is shorter than the drive permission lower limit value corresponding period T_l, the ECU **300** releases the drive inhibition state of the starter **200** when the elapsed time t_ct measured by the measurement timer reaches the drive permission lower limit value corresponding period T_l. On the other hand, if the time interval t_crk between the crank signals, which are the first reverse rotation crank signal and the second reverse rotation crank signal, is equal to or longer than the drive permission lower limit value corresponding period T_l, the ECU **300** releases the drive inhibition state of the starter **200** when the elapsed time t_ct measured by the measurement timer reaches the time interval t_crk.

As a result, at a time point earlier than the time point when the third reverse rotation crank signal is input, the drive inhibition state of the starter **200** can be appropriately released depending on the rotation state of the engine **101**, and the period of the drive inhibition state does not thus unnecessarily extend.

Moreover, the ECU **300** determines whether the rotation state of the engine **101** is the forward rotation state or the reverse rotation state based on the change in the output signal of the crank angle sensor. As a result, the rotation state of the engine **101** is accurately detected, and an erroneous operation is thus prevented. For example, the drive inhibition state of the starter **200** is not released by mistake in such a rotation state that the drive inhibition state should not be released.

As described above, according to the first embodiment, the drive inhibition state of the starter is released when the drive inhibition release determination period set depending on the time interval between the time point when the first reverse rotation crank signal is detected and the time point when the second reverse rotation crank signal is detected and the drive permission lower limit value corresponding period corresponding to the starter drivable RPM lower limit value elapses before the third reverse rotation crank signal is input. As a result, the drive inhibition state of the starter can be properly released depending on the rotation state of the internal combustion engine, and a period of the drive inhibition state of the starter can be reduced. Thus, when the restart requirement is satisfied, the starter can be quickly driven to restart the internal combustion engine.

According to the first embodiment, the case where the starter is brought into the drive inhibition state after the rotation state of the internal combustion engine is determined to change to the reverse rotation state based on the detection result of the reverse rotation crank signal has been exemplified for description, but the present invention is not limited to this case. Specifically, the present invention can also be applied to a case where the starter is brought into the drive inhibition state after the rotation state of the internal combustion engine is determined to change from the forward rotation state to the reverse rotation state based on a calculation result of the RPM of the internal combustion engine, and the same effects can be provided also in this case.

What is claimed is:

1. An internal combustion engine automatic stop/restart device for stopping an internal combustion engine when an automatic stop requirement for automatically stopping the internal combustion engine is satisfied, and restarting the internal combustion engine when a restart requirement for restarting the internal combustion engine is satisfied after the automatic stop requirement is satisfied, the internal combustion engine automatic stop/restart device comprising:

a starter for starting the internal combustion engine;

an RPM calculation unit for calculating an RPM of the internal combustion engine based on a crank signal, which is an output signal of a crank angle detection unit for detecting a crank angle of the internal combustion engine;

a rotation direction determination unit for determining whether the crank signal output by the crank angle detection unit is a forward rotation crank signal corresponding to a case where a rotation state of the internal combustion engine is a forward rotation state or a reverse rotation crank signal corresponding to a case where the rotation state is a reverse rotation state;

a drive inhibition determination unit for bringing the starter into a drive inhibition state when the RPM calculated by the RPM calculation unit is not included in a drivable

RPM range from a starter drivable RPM lower limit value to a starter drivable RPM upper limit value, which are prescribed in advance, and bringing the starter into the drive inhibition state when the crank signal output by the crank angle detection unit changes from the forward rotation crank signal to the reverse rotation crank signal;

a drive inhibition release unit for calculating, when the crank angle detection unit outputs a second reverse rotation crank signal after outputting a first reverse rotation crank signal, which is a first reverse rotation crank signal when the forward rotation crank signal changes to the reverse rotation crank signal, a time interval between a first time point when the first reverse rotation crank signal is input and a second time point when the second reverse rotation crank signal is input, and releasing the drive inhibition state when a third reverse rotation crank signal is not input following the second reverse rotation crank signal until a drive inhibition release determination period set depending on the calculated time interval and a drive permission lower limit value corresponding period, which is a period acquired by converting the starter drivable RPM lower limit value, elapses from the second time point; and

a restart control unit for driving the starter to restart the internal combustion engine when the restart requirement is satisfied and the starter is not in the drive inhibition state,

wherein when the time interval is shorter than the drive permission lower limit value corresponding period, the drive inhibition release unit sets the drive permission lower limit value corresponding period as the drive inhibition release determination period, and when the time interval is equal to or longer than the drive permission lower limit value corresponding period, the drive inhibition release unit sets the time interval as the drive inhibition release determination period.

2. An internal combustion engine automatic stop/restart device according to claim **1**, wherein the rotation direction determination unit determines whether the crank signal output by the crank angle detection unit is the forward rotation crank signal or the reverse rotation crank signal depending on a LOW period, which is a total period when the crank signal can take a LOW value in each cycle.

3. An internal combustion engine automatic stop/restart method to be carried out by an engine control unit (ECU) in an internal combustion engine automatic stop/restart device including a starter for starting an internal combustion engine, the internal combustion engine automatic stop/restart method, comprising:

an automatic stop control step of stopping the internal combustion engine when an automatic stop requirement for automatically stopping the internal combustion engine is satisfied;

an RPM calculation step of calculating an RPM of the internal combustion engine based on a crank signal, which is an output signal of a crank angle detection unit for detecting a crank angle of the internal combustion engine;

a drive inhibition determination step of bringing the starter into a drive inhibition state when the RPM calculated in the RPM calculation step is not included in a drivable RPM range from a starter drivable RPM lower limit value to a starter drivable RPM upper limit value, which are prescribed in advance, and bringing the starter into the drive inhibition state when the crank signal output by the crank angle detection unit changes from a forward rotation crank signal to a reverse rotation crank signal;

a drive inhibition release step of calculating, when the crank angle detection unit outputs a second reverse rotation crank signal after outputting a first reverse rotation crank signal, which is a first reverse rotation crank signal when the forward rotation crank signal changes to the reverse rotation crank signal, a time interval between a first time point when the first reverse rotation crank signal is input and a second time point when the second reverse rotation crank signal is input, and releasing the drive inhibition state when a third reverse rotation crank signal is not input following the second reverse rotation crank signal until a drive inhibition release determination period set depending on the calculated time interval and a drive permission lower limit value corresponding period, which is a period acquired by converting the starter drivable RPM lower limit value, elapses from the second time point; and

a restart control step of driving the starter to restart the internal combustion engine when a restart requirement for restarting the internal combustion engine is satisfied after the automatic stop requirement is satisfied, and the starter is not in the drive inhibition state,

wherein the drive inhibition release step comprises setting the drive permission lower limit value corresponding period as the drive inhibition release determination period when the time interval is shorter than the drive permission lower limit value corresponding period, and setting the time interval as the drive inhibition release determination period when the time interval is equal to or longer than the drive permission lower limit value corresponding period.

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